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NORMAN WELLS RESEARCH AND MONITORIN
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NORMAN WELLS RESEARCH AND MONITORING PROGRAM

Fourth Annual Summary Report

May 1987

PREPARED BY:

BOREAL ECOLOGY

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NORMAN WELLS RESEARCH and MONITORING PROGRAM

Fourth Annual Summary Report

Prepared for:

Environmental Protection
Conservation and Protection
Department of the Environment
Yellowknife, N.W.T.

By:
Boreal Ecology Services Ltd.
Yellowknife, N.W.T.

March 1987

DISCLAIMER

This summary report was prepared by Boreal Ecology Services Ltd. of Yellowknife for Environmental Protection, Department of the Environment. The summaries are based on reports provided by the contributing agencies and the first, second, and third annual reports of the Norman Wells Research and Monitoring Program. Observations and results reported here are interim findings and should not be regarded as final conclusions unless otherwise noted.

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INTRODUCTION

The Environmental Assessment (EA) Panel examining the Norman Wells Oilfield Expansion and Pipeline Project reported its findings to the Minister of the Environment in January 1981. Numerous recommendations were made regarding research and monitoring of the effects of oilfield and pipeline construction and operations. In August of 1981, the oilfield expansion and pipeline projects were granted approval by the Federal Cabinet. Approvals were contingent upon the submission of further information by the proponents, and were subject to a two-year delay to enable preparations by government, native organizations, and the public.

In August of 1982, the Deputy Minister of the Government of the Northwest Territories Department of Renewable Resources, Mr. James Bourque, proposed the development and implementation of an intergovernmental research and monitoring program for the oilfield expansion and pipeline projects. The purpose of this program was to test the validity of impact predictions identified during the environmental assessment and review process, and to test the effectiveness of mitigative measures identified during the regulatory process. Mr. Bourque further proposed four objectives for the program:

1. to determine and quantify environmental impacts and to examine recovery processes,
2. to compare actual and predicted impacts,
3. to evaluate the long-term effectiveness of mitigative measures, and
4. to prepare environmental recommendations applicable to future northern pipeline and oilfield developments.

In September of 1982, a Working Group was established to develop and implement a research and monitoring program. The Working Group included representatives from:

The Department of Renewable Resources (GNWT)
The Department of the Environment (DOE)
The Department of Indian Affairs and Northern Development (DIAND)
The Department of Fisheries and Oceans (DFO)
The Department of Energy, Mines and Resources (EMR).

Over time, the Working Group has expanded to include:

Esso Resources Canada Limited
Interprovincial Pipe Line (NW) Limited
Dene Nation
Federal Pipeline Coordinator's Office
The Department of Agriculture (DOA)
The University of Alberta (U of A)
The National Research Council (NRC)

The initial task of the Working Group was to identify all environmental issues and concerns related to northern pipelines and oilfield developments. To this end, the reports of the Berger Commission and of the Norman Wells and Alaska Highway Gas Pipeline Environmental Assessment panels were thoroughly reviewed. The transcripts of the N.W.T. Water Board public hearings and reports resulting from the National Energy Board hearings were also reviewed. In order to make use of the extensive knowledge and experience gained in Alaska from the construction of the Trans-Alaska Pipeline System, a member of the Working Group visited Alaska in January of 1983 and consulted extensively with Federal and State officials who had been directly involved with environmental

regulation and monitoring. In return, two U.S. officials travelled to Yellowknife in March of 1983 and conducted a northern pipelines workshop for interested representatives of government, industry, native organizations, and the public.

Once the available information had been collected and assessed, the members of the Working Group established a set of priority environmental issues. For each priority issue, a research and monitoring project was developed under the sponsorship of one or more of the participating organizations. Over time, the list of priorities for research and monitoring has grown and now includes:

1. revegetation and restoration (including remote sensing)
2. artificial island integrity during Mackenzie River breakup
3. oilfield emissions and air quality
4. terrain performance along the pipeline
5. effects and effectiveness of wood chip insulation
6. thermal regime and ground stability along the pipeline
7. soil temperatures
8. forest ecosystem disturbances
9. contaminants pathways in the Mackenzie River
10. fish quality and physiological condition downstream of the Norman Wells refinery
11. aquatic impacts from the construction of pipeline stream crossings
12. snow geese and their habitat use
13. disturbances to raptors
14. disturbances to terrestrial wildlife
15. renewable resource harvesting

Preliminary field reconnaissance for most of the projects was carried out during the summer of 1983, and the majority of research and monitoring was well underway by the time pipeline construction began

in January 1984.

Now, in March of 1987, six years following the Environmental Assessment and Review Panel report, the construction period is over and the oilfield and pipeline facilities have been operating for two years.

PROGRAM COORDINATION

The Working Group of the Norman Wells Research and Monitoring Program meets formally at a northern location in the fall of each year. At these meetings, the members of the Working Group discuss the results of individual projects, coordination between studies, requirements for further research and monitoring, and the preparation of environmental recommendations for future northern pipelines and oilfield developments.

The Working Group strongly supports the concept of community-based environmental monitoring and welcomes the participation of the public, both at its regular meetings and in its field projects.

Questions on the scope of the Norman Wells Research and Monitoring Program should be addressed to the Working Group Chairman:

Dr. Brian Wilson
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The following sections summarize the results of the research and monitoring projects conducted to date. This summary is not intended to be a definitive or exhaustive description of each study and its results, but rather a collection of relevant information for the interested public. Persons wishing more specific information are referred to the researchers and to the specific reports listed in the individual project summaries.

Reports Available

Environmental Protection Service, 1984. The Norman Wells Research and Monitoring Program, Status Report. June 27, 1984. 15pp.

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1. INTERPROVINCIAL PIPE LINE (NW) LTD. MONITORING PROGRAM

Agencies Participating

Interprovincial Pipe Line (NW) Ltd.
in cooperation with the Government of the Northwest Territories and the Department of Indian Affairs and Northern Development, with assistance from the Department of Energy, Mines and Resources, Agriculture Canada, and the National Research Council.

Start-up Date

1980-82 Baseline studies
1983-85 Construction monitoring
1984-86 Post-Construction monitoring

Objectives of Monitoring

1. to evaluate the environmental impact of pipeline construction and operation,
2. to identify the need for remedial measures and/or a change in design or procedures,
3. to assess the effectiveness of environmental protection measures, and
4. to establish reasonable environmental recommendations for future pipeline developments in the north.

Results to Date

Baseline Monitoring Studies 1980-82.

Raptor Monitoring

Interprovincial Pipe Line (NW) conducted raptor surveys along the Norman Wells pipeline route in 1980 and 1981 to establish baseline conditions and raptor protection zones. Thirteen nesting areas were identified and three of 44 nests were occupied in 1981.

Wildlife Monitoring

Interprovincial conducted wildlife surveys of borrow pits and facility sites in the summer of 1982 and moose surveys along the Mackenzie River and Norman Wells Pipeline route in the winter of 1982. Low densities of animals were observed and the only significant concentrations occurred on alluvial islands of the Mackenzie River.

Aquatic Monitoring

Intensive surveys were conducted on the Great Bear River and Mackenzie River to characterize the fish populations and physical streambed in the vicinity of the pipeline crossings. Similar studies were undertaken for all Interprovincial facility sites.

Late winter surveys were conducted of all watercourses to assess the potential for fish overwintering in the vicinity of the pipeline crossings. Depth of water, flow rates, and dissolved oxygen concentrations were the major criteria in assessing overwintering potential.

Waterfowl

Surveys were conducted in the spring of 1981 and 1982 to determine open water conditions and waterfowl distributions before and during break-up.

Other Studies

Interprovincial Pipe Line (NW) also undertook more than 75 other studies related to terrain typing and performance, erosion control, and reclamation.

Construction Monitoring 1983-1985.

Aquatic Monitoring

Interprovincial undertook several water quality monitoring programs in relation to pipeline construction activities in 1984 and 1985. Intensive water quality monitoring programs were undertaken at the Mackenzie River, Great Bear River, and Bosworth Creek, all of which are used as municipal water sources. Studies to determine fisheries habitat potential in the vicinity of pipeline crossings and to ascertain any significant changes to water quality resulting from construction activities were conducted on thirty-four other watercourses.

The results of the water quality monitoring programs indicated that pipeline construction activities did not produce significant environmental impacts. Clear water conditions prevailed throughout blasting, excavation, and backfilling on those water courses used as municipal water sources. Several other potability parameters sampled on these watercourses also demonstrated that water throughout the construction period remained a suitable source for domestic consumption.

Monitoring programs established to evaluate the impact of construction on fisheries habitat determined that only 18 of 34 water courses sampled had water quality parameters conducive to overwintering fisheries in the vicinity of the pipeline crossings. A continuation of free water flow and high concentrations of dissolved oxygen immediately downstream of these crossings indicated that construction did not impair these habitat criteria.

Wildlife Monitoring

Wildlife monitoring during construction involved three separate programs. Representatives of various Hunters and Trappers Associations were contracted by IPL to conduct wildlife track counts along the right-of-way during construction in 1984 and 1985. The second monitoring program involved track densities and browse use measurements along rectangular sampling transects with a 4 km perimeter. Two pairs of transects were established in each of six sampling areas and data were collected in January and March, 1985. The third program required IPL, contract, and regulatory personnel to record sightings of wildlife as encountered.

Utilization of available browse was found to be very low with only four percent of sampled shrubs showing signs of browsing. The majority of browsing by moose (74 percent) was observed beyond 750 m from the right-of-way. However, some moose browsing was observed as close as 150 m from the right-of-way. The distribution of browsing by hare suggested no avoidance of habitats adjacent to pipeline-related clearings.

From the small numbers of tracks seen during the monitoring studies, it can be inferred that the population of animals in the study regions was exceptionally low. Furbearer track data demonstrated no consistent positive or negative responses to habitats adjacent to

pipeline clearings, although the actual cleared areas were usually avoided by the animals. Track densities were too low for other wildlife species to permit any assessment of trends in abundance.

While some avoidance of habitat adjacent to the right-of-way by moose was suggested by these data, the very low utilization of browse, even in areas well removed from the pipeline, indicated that a reduction of wildlife carrying capacity was unlikely.

Throughout the period of mainline construction, numerous wildlife were observed on or immediately adjacent to the right-of-way. The track count data collected by representatives of Hunters and Trappers Associations also provided evidence that all of the major wildlife species, including moose, at least periodically utilized the right-of-way. It appeared that any displacement of wildlife away from the right-of-way was minor and of short duration.

POST-CONSTRUCTION MONITORING - 1984/86

Terrain Monitoring

Beginning in April 1984, routine surveillance patrols were conducted on a weekly basis and in certain areas more frequently. Included among these patrols were monthly investigations and readings at more than 50 instrumented sites. Furthermore, in 1984, 1985, and 1986 there were a series of special monitoring trips to investigate slopes.

Overall, terrain performance has been satisfactory. Areas which experienced active erosion represent a minor portion of the total right-of-way. The most extensive change in terrain condition continues to be subsidence of the ditch line below the original ground surface. Placement of borrow material to backfill subsided

ditch was undertaken in summer and winter 1986 and will be done again in 1987 to address new locations with subsided ditch.

No major slope instability problems occurred although minor slumping was evident at a few locations. In general, wood chip insulation has performed in accordance with expectations.

Aquatic Monitoring

Post-construction surveys of pipeline watercrossings were conducted at least once per week beginning in April 1984. Detailed surveys were undertaken in July 1984, 1985, and 1986 in which all major and most minor watercourses were inspected. Specifically, the approaches and instream ditchline were examined for stability and scour, any pipeline-related alterations to the watercourse were evaluated, upstream and downstream areas were compared to evaluate potential sedimentation concerns, and the water crossings were assessed to determine whether the right-of-way was contributing to the degradation of water quality or aquatic habitat.

Problems identified included subsidence of the ditch line on watercourse approaches and insufficient bank armouring. Problem sites noted in 1984 and 1985 were corrected in winter restoration programs and those noted during the 1986 post-construction monitoring survey will be corrected in 1987. Sedimentation downstream of the pipeline crossing has been minimal or non-existent.

Several physical and chemical water quality parameters were monitored in the summer of 1985 at the Mackenzie River, Great Bear River, and Bosworth Creek pipeline crossings, all of which are used as domestic water sources. These analyses indicated that pipeline construction and operation had not impaired water quality at these watercourses one year after construction. No significant increases or decreases

in any of the twenty chemical or physical parameters analyzed occurred downstream of the pipeline crossings relative to background levels recorded immediately upstream of the crossings.

Raptor Monitoring

IPL participated in a cooperative raptor monitoring program with the Department of Renewable Resources, Government of the Northwest Territories (Matthews, 1986) by providing logistical support for surveys conducted in the summers of 1984, 1985, and 1986.

Thirty-nine nests were recorded in 1986 of which seven were ledge nests and thirty-two were stick nests. Nine of the 39 nests were occupied, an increase of four from the number recorded in 1985. In 1981, prior to pipeline development, only three of 44 nests were occupied (Table 1.1).

Peregrine falcons were observed at three nesting areas in 1986 and 1985 in comparison to observations at two nesting areas in all other study years. However, there were four active ledge nests in 1986 in comparison to one active ledge nest in 1985. In the six years for which raptor monitoring has been conducted, 1986 was the only year in which four nests were occupied and the only year in which all Peregrine falcon nest sites along the pipeline route were occupied. The eight Peregrine young produced in 1986 also exceeded productivity of all other monitored years. The second highest rate of productivity of all other monitored years was five young produced in 1983, after the first year of construction.

Golden Eagles produced three young in 1986. The largest number of Golden Eagle young previously produced along the pipeline route was two, produced in 1983.

A comparison of raptor observations and productivity from 1980 to 1986 does not indicate that the development of the pipeline has significantly impacted raptor populations in the vicinity of the right-of-way.

Wildlife Monitoring

Wildlife monitoring studies were undertaken along the pipeline route from April 1985 to May 1986 to assess the effects of the pipeline right-of-way on local wildlife distributions and abundance. Study components included:

1. two aerial surveys designed to provide comparable estimates of moose densities adjacent to and several km from the right-of-way (November 1985 and March 1986);

2. two track count surveys designed to provide comparable, habitat-specific estimates of furbearer track densities at set intervals from the right-of-way (November 1985 and March 1986);

3. track observations by Hunters and Trappers Association (HTA) members during snowmobile coverage of the right-of-way (November 1985 to April 1986); and

4. wildlife observations by IPL personnel during weekly surveillance flights of the right-of-way (April 1985 to May 1986).

Intensive aerial surveys of sample blocks or quadrats 4 km^2 in size were used to compare moose densities adjacent to and away from the right-of-way. Although moose densities along most of the corridor were low (i.e., <0.1 moose/km^2), the Jean Marie Creek area

(kp 550-580) supported moderate levels of activity and was selected for the intensive quadrat surveys. Moose densities close to the right-of-way (0.16 moose/km^2) were greater than those observed more than 2 km from the right-of-way (0.10 moose/km^2) (Table 1.2). However, statistical comparisons revealed that these two densities were not significantly different.

Track surveys were conducted in those habitat types which had supported moderate to high levels of furbearer activity during the previous winter. In almost all cases, habitat-specific track densities were statistically similar for all distance-from-right-of-way categories. The only exception occurred in mixed wood forests, where track densities of snowshoe hare were significantly lower on right-of-way transects than in adjacent undisturbed vegetation, suggesting some avoidance of actual cleared right-of-way.

To assess the effects of the right-of-way on localized wildlife movements, the track patterns of animals encountering the right-of-way were recorded incidentally during track counts and aerial surveys (Table 1.3). Similar to the first year of study, large mustelids (i.e., marten, mink) demonstrated successful crossings on approximately 50 percent of all crossing attempts. Ungulates typically approached and entered the right-of-way directly, with 43 percent crossing without deflection along the right-of-way. Wolves used the right-of-way as a travel corridor, frequently following it for long stretches with only short forays into adjacent cover.

The data collected to date indicate that for the smaller, territorial furbearers, the 25 m wide right-of-way, with its open herbaceous cover, represents less favourable habitat than denser shrub or forest cover, and its development likely results in minor modifications to

the shape and boundaries of those territories. The right-of-way, in its present state, also appears to discourage the cross-right-of-way movements of some of the smaller furbearers. However, based on two years of track data, there is no evidence to suggest that these impacts have resulted in reduced animal activity even in the immediate vicinity of the right-of-way.

For larger mammals, data indicate that the right-of-way represents a more positive habitat alteration. Because it is cleared of dense vegetation and seldom maintains deep accumulations of snow, it serves as an attractive corridor for inter-range travel and perhaps long-range dispersal. Through revegetation efforts, the right-of-way currently supports a productive forage source (i.e. grasses) not readily found in adjacent undisturbed areas. In the next several years, it will also be colonized by palatable browse species over much of its area. Considering the frequency of black bear sightings along the pipeline during May, it is possible that the right-of-way is already an attractive source of high protein forage for these animals immediately following their denning period.

To date, survey data have not demonstrated the existence of significant positive or negative impacts from the pipeline development and it appears that the right-of-way is a habitat component of limited significance to local wildlife populations. Nevertheless, in recognition of the need for longer-term effects monitoring, a further year of monitoring will be undertaken to provide a replicate year of post construction data collected under the present study design.

Revegetation Monitoring

A detailed revegetation monitoring program was undertaken in late August and early September in 1984, 1985, and 1986. By means of an

aerial survey, plant cover was assessed in qualitative terms along the right-of-way and associated construction sites. One hundred and thirty permanently marked transects were monitored to provide a quantitative assessment of vegetation cover. Sites selected for quantitative vegetation monitoring included: all major terrain types; areas where full, partial, or no seeding was undertaken; major slopes; off right-of-way sites; and areas which received special treatments including twenty Revegetation Trial Sites established in cooperation with the Department of Indian Affairs and Northern Development to test the effectiveness of seeding and/or fertilization.

Generally, revegetation results were highly favourable. Total plant cover on areas first seeded in 1984 averaged 42 percent in 1986 which is an increase of 14 percent from the 1985 cover values. Mean plant cover on areas first seeded in 1985 was 44 percent compared to 18 percent in 1985 (Tables 1.4, 1.5, 1.6, and 1.7). In both cases, about three-fourths of the cover was provided by seeded grasses and one-fourth by native vascular plants.

Boreal creeping red fescue continued to provide the most ground cover in 1986. In order of decreasing abundance, creeping foxtail, Revenue slender wheatgrass, and Climax timothy were also common. Reed canary grass was locally abundant in wet areas. The cover of Kodiak fall rye, an annual cereal crop which was seeded on sandy areas, declined as expected from 9.5 percent in 1984 to 0.5 percent in 1985 and was largely absent in 1986 (Tables 1.4, 1.5, 1.6, and 1.7).

The effectiveness of seeding and fertilizing was demonstrated at the revegetation trial sites. At these sites, established in 1984, differences among treatments, still quite evident in 1985, were nearly absent in 1986. Total vascular plant cover on seeded and fertilized plots (44%) was essentially no different from seed only

(45%) or fertilizer only (51%) plots and only slightly higher than untreated (36%) plots. Second year plant cover differences on sites established in 1985 were still quite distinct, seeded and fertilized plots having over twice the cover of untreated plots and 1.2 and 1.6 times the cover of fertilizer only and seed only plots respectively. While these results suggest that by the end of the third growing season similar levels of plant cover can be achieved using a variety of treatments, only the seed and fertilizer treatment provided adequate erosion protection during the first two years following construction.

IPL also undertook a program to test the effectiveness of shrub cuttings to improve terrain stability at selected locations along the right-of-way. Of the 1033 cuttings planted in the spring of 1985, only 425 or 41 percent were surviving in August 1986. While insufficient time had passed to derive conclusions, it is apparent that the shrubs will not significantly contribute to terrain stability for several years.

Aerial Photography and Analysis

An aerial photography program has been underway since 1980 to provide a permanent chronological record of terrain and landscape conditions before, during, and after construction. Aerial photographs were taken by IPL in 1980 and by Indian and Northern Affairs Canada annually from 1983 to 1985.

In July 1986, Interprovincial Pipeline undertook black and white panchromatic photography of the entire pipeline right-of-way at a scale of 1:10,000. Colour photography also was taken at 29 selected sites at a scale of 1:4000. An analysis of ground conditions on the right-of-way as shown on the photographs was then conducted. Specifically, the analysis provided a log by kilometer post of

vegetation cover and type and major physical disturbances such as ground settlement, erosion features, slides, and ditch line settlement. Results from the analyses have been included elsewhere in this report. IPL will again produce an aerial photographic record in the summer of 1988.

Conclusions

The results of the post-construction monitoring programs indicate that no significant environmental impacts have resulted to date from pipeline construction or operations. Since completion of construction, no significant variance from predicted performance have been observed with respect to condition of the right-of-way. Conscientious monitoring and surveillance programs will continue to ensure that any further terrain changes are identified as they develop and to allow for early restorative works where required.

Proposed Follow-up Post Construction

Interprovincial will continue with the established programs to the dates shown on Table 1.8.

Reports Available

Reports are available for viewing at the Interprovincial office in Edmonton, Alberta. Copies are also available for viewing at DIAND, Yellowknife, NWT; GNWT, Yellowknife, NWT; NEB, Ottawa, Ontario; Boreal Institute, Edmonton, Alberta; and Arctic Institute, Calgary, Alberta.

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Wildlife Monitoring

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Contact

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(403) 420-5210

Table 1.1 Summary of raptor observations along pipeline right-of-way 1980 - 1986

Nesting Area	Year of Survey 1980	1981	1983	1984	1985	1986
A	S[1] GE[2]-ad[3]	2 AK-ad	2 PF-ad	2 PF-ad	2 PF-ad 3 PF-yg	2 PF-ad 3 PF-yg
	1 GE-imm		1 PF-imm	1 PF-imm	2 Rav-ad 3 Rav-yg	4 Rav-ad
B	0	1 GE-ad	2 Rav-ad	2 Rav-ad 3 Rav-yg 2 RT-ad 2 RT-yg	0	1 RT-ad 2 Rav-ad
C	1 PF-ad	2 PF-ad	1 PF-ad	2 PF-ad	2 PF-ad 2 GE-ad	4 PF-ad 2 PF-yg
	1 PF-imm	1 PF-imm	4 PF-imm	1 GE-ad 1 GE-imm	1 GE-yg	2 GE-ad 1 GE-yg
D	0	0	1 GHO-ad 1 GHO-yg	0	2 GHO-ad	0
E	1 PF-imm	1 PF-ad	1 RT-ad	2 PF-ad 1 GE-ad	2 PF-ad	2 PF-ad 3 PF-yg
		4 PF-yg	2 RT-yg	1GE-yg		
F	0	1 RT-ad 3 Rav-undet		2 Rav-ad 3 Rav-yg	1 Rav-ad 3 Rav-yg	2 Rav-ad
G	1 GE-ad 1 GE-imm	1 GE-ad	0	0	0	1 AK-ad
H	0	0	0	0	0	0
I	0	1 AK-ad	2 GE-ad 2 GE-yg	2 GE-ad 1 GE-yg	2 GE-ad	2 GE-ad 2 GE-yg
J	0	1 Rav-undet				
K	0	0	0	0	0	0
L	-[4]	-[4]	0	0	0	0
M	1 BE-ad 3 BE-imm	0	1 BE-ad 1 GE-ad	0	0	0

[1] Number of birds observed in or near the nesting area of species and age indicated.

[2] Species of raptor observed: GE Golden Eagle; BE Bald Eagle; Pf Peregrine Falcon; AK American Kestrel; RT Red Tailed Hawk; Rav Raven; GHO Great Horned Owl

[3] Age of bird: ad adult; imm immature; yg young (nestling); undet undetermined age

[4] Nesting area not surveyed in 1980 or 1981.

Table 1.2 Moose densities observed during quadrat surveys in the Jean Marie Creek area of the Norman Wells-Zama oil pipeline corridor (November 1985)

Experimental Quadrats

Quadrat	Area (km²)	No. Moose	Density (No./km²)
1	3.6	0	0
2	4.9	0	0
3	4.6	0	0
6	3.7	2[1]	0.54
7	3.3	2[1]	0.61
12	4.1	0	0
13	4.0	2[1]	0.50
16	3.4	0	0
18	4.5	0	0
19	4.0	0	0
TOTAL	40.1	6	$\bar{x}$ = 0.16

Control Quadrats

Quadrat	Area (km²)	No. Moose	Density (No./km²)
4	3.6	0	0
5	4.6	0	0
8	4.5	0	0
9	4.0	1[2]	0.50
10	5.7	0	0
11	5.6	0	0
14	4.4	0	0
15	3.9	2[1]	0.51
17	4.0	0	0
20	4.0	0	0
TOTAL	44.3	3	$\bar{x}$ = 0.10

[1] - cow/calf pair
[2] - bull

Table 1.3 Observed wildlife responses to the right-of-way

Kp (Approx.)	Species	No. of Approaches	Nature of Approach[1]	ROW Crossing Details	Nature of Departure[1]
535	Moose	1	N/A	-Feeding to within 40 m of ROW. No crossing.	N/A
560	Moose	1	Direct	-Tracks followed cutline to ROW, followed ROW for 30 m, then completed crossing.	Direct
585	Wolf	4	Oblique	-1 or 2 sets of tracks followed ROW for much of its length exiting into adjacent cover for short distances (i.e., < 200 m).	Oblique
631	Wolf	1	Unknown	-Tracks followed ROW for 2 km. Approach and exit obscured by wind packing.	Unknown
633	Caribou	1	Direct	-6 sets of tracks crossed ROW directly, following Trout River.	Direct
633 -646	Wolf	1	Unknown	-Tracks followed ROW continuously. Approach to ROW obscured by wind packing.	Oblique
641	Caribou	1	Direct	-5 sets of tracks crossed ROW directly, following a small stream.	Direct
643	Caribou	1	Direct	-8 sets of tracks followed ROW for 100 m, then completed crossing.	Direct
728	Ungulate	1	Direct	-1 set of tracks followed ROW for 25 m, then completed crossing.	Direct
729	Caribou	1	Direct	-8 sets of tracks followed ROW for 50 m, exiting on same side as approach.	Direct
730	Caribou	1	Direct	-15 sets of tracks entered ROW, 7 followed ROW for 50 m before completing the crossing, 8 crossed directly.	Direct

[1] Direct = 45° to 90° to the ROW.
Oblique = <45° to the ROW.

Table 1.4 Revegetation monitoring: mean percentage seeded and native vascular cover along permanent transects on areas seeded in winter 1984

Site	No. Transects (All Spreads)	Mean Percent Cover																					
		Seeded Cover								Native Vascular								Total Vascular					
		KP 0-190			KP 326-527			KP 662-868			Ave**			KP 0-190			KP 326-527			KP 662-868			Ave**		
		*1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Right-of-way (Seeded portions only)																							
Overland Transects	12	14	16	24	13	24	38	11	11	36	13	18	32	7	10	21	5	10	11	2	6	11	6	9	15
Slope Transects	10	15	19	22	14	21	34	26	24	27	17	21	30	7	14	17	3	6	12	8	13	12	5	9	13
All Transects	22	14	17	23	13	22	36	17	18	31	15	20	31	7	12	19	4	8	11	5	9	12	6	9	14
Right-of-way (Organic not Seeded)	4	0	3	0	0	0	1	0	0	0	0	1	1	7	10	26	4	12	17	1	0	1	4	8	16
Borrow Sites	3		-		12	14	22	7	3	11	11	10	18		-		1	3	3	2	7	21	1	4	9
Spoil Sites	7	11	26	42	11	21	48	20	37	59	13	25	49	3	4	21	1	1	3	0	5	8	1	2	8
Access Roads Seeded	2	16	10	11		-			-		16	10	11	6	8	10		-			-		6	8	10
Access Roads Not Seeded	1	0	0	0		-			-		0	0	0	11	3	15		-			-		11	3	15
Campsite	1		-			-		5	26	38	5	26	38		-			-		7	20	18	7	20	18
Wood Harvest Sites																							
Skid Trail Seeded	1	11	24	41		-			-		11	24	41	4	5	4		-			-		4	5	4
Skid Trail Not Seeded	1	0	0	0		-			-		0	0	0	5	9	32		-			-		5	9	32
Cutover Not Seeded	2		-		0	0	0		-		0	0	0					-		10	23	46		-	
Revegetation Trial Sites																							
No Seed/No Fertilizer	8	0	1	1	0	0	0		-		0	1	1	8	13	28	6	18	43		-		7	15	35
Seed Only	8	5	10	16	7	19	12		-		5	6	14	6	9	13	13	29	48		-		10	19	31
Fertilizer Only	7	1	2	2	0	0	0		-		1	1	1	9	18	36	14	36	67		-		12	25	50
Seed/Fertilizer	8	14	16	24	11	28	35		-		13	21	28	7	10	21	11	13	9		-		8	11	16

Site	No. Transects (All Spreads)	Mean Percent Cover																					
		Total Vascular																					
		KP 0-190			KP 326-527			KP 662-868			Ave**												
		1	2	3	1	2	3	1	2	3	1	2	3										
Right-of-way (Seeded portions only)																							
Overland Transects	12	20	26	44	10	33	49	13	17	47	16	27	47										
Slope Transects	10	22	33	39	14	27	46	34	37	39	22	31	43										
All Transects	22	21	29	42	17	30	48	23	27	42	20	29	45										
Right-of-way (Organic not Seeded)	4	7	12	26	4	12	18	1	0	1	4	9	14										
Borrow Sites	3		-		13	16	25	9	10	31	12	14	27										
Spoil Sites	7	15	30	63	12	22	51	20	41	67	14	28	57										
Access Roads Seeded	2	22	18	21		-			-		22	18	21										
Access Roads Not Seeded	1	11	3	15		-			-		11	3	15										
Campsite	1		-			-		12	45	56	12	45	56										
Wood Harvest Sites																							
Skid Trail Seeded	1	15	29	45		-			-		15	29	45										
Skid Trail Not Seeded	1	5	9	32		-			-		5	9	32										
Cutover Not Seeded	2	10	23	46		-		10	23	46	10	23	46										
Revegetation Trial Sites																							
No Seed/No Fertilizer	8	8	14	29	6	18	43		-		7	14	34										
Seed Only	8	11	19	30	14	31	52		-		12	20	45										
Fertilizer Only	7	10	21	38	15	34	67		-		12	27	51										
Seed/Fertilizer	8	20	26	44	22	41	44		-		21	32	44										

* Growing season following seeding
** Weighted average
- Indicates no data gathered

Table 1.5 Revegetation monitoring: mean percentage seeded and native vascular cover along permanent transects on areas seeded in winter 1985

Site	No. Transects	Mean Percent Cover															
		Seeded Cover						Native Vascular						Total Vascular			
		KP 190-336		KP 528-662		Ave**		KP 190-336		KP 528-662		Ave**		KP 190-336		KP 528-662		Ave**	
		*1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Right-of-way (Seeded Portion Only)																			
Overland Transects	13	9	24	14	25	12	25	5	14	6	12	6	13	14	38	20	38	18	38
Slope Transects	8	7	14	18	33	14	28	3	11	1	2	2	4	10	25	19	34	16	32
All Transects	21	8	21	15	28	13	26	4	13	4	8	4	10	12	34	19	36	17	36
Access Roads	1	7	19	-	-	7	19	13	32	-	-	13	32	20	50	-	-	20	50
Borrow Sites																			
Spoil Sites	2	-	-	30	53	30	53	-	-	0.2	1	0.2	1	-	-	30	54	30	54
Campsite	1	7	46	-	-	7	46	2	0	-	-	2	0	9	46	-	-	9	46
Wood Harvest																			
Not Seeded	2	0	0	0	0	0	0	9	43	16	34	13	39	9	43	16	34	13	39
Revegetation Trial Sites																			
Not Seeded/Not Fertilized	9	0.4	1	0.2	1	0.3	2	4	17	7	13	6	12	5	18	7	14	6	15
Seed Only	12	6	13	4	10	5	11	5	12	4	8	4	10	11	25	9	17	10	22
Fertilizer Only	11	0.3	3	0.6	2	0.5	3	9	28	10	22	9	26	9	31	11	24	10	29
Seed and Fertilizer	12	9	21	13	24	11	23	5	12	7	13	6	13	14	31	19	37	18	36

* Growing season following seeding
** Weighted average
- Indicates no data gathered.

Table 1.6 Revegetation monitoring:
mean percentage cover of grasses seeded in 1984[1]

Species	Mean seeded cover (%) 1984	1985	1986
Common Kentucky Bluegrass	0.1	0.1	0.1
Boreal Creeping Red Fescue*	6.5	10.6	17.7
Durar Hard Fescue*			0.9
Revenue Slender Wheatgrass	2.8	3.8	3.3
Creeping Foxtail	0.8	2.3	5.0
Vantage Reed Canary Grass	0.6	1.0	2.1
Climax Timothy	2.2	1.9	3.3
Total	13.7	19.8	32.4
Kodiak Fall Rye**	9.5	0.5	0.0

[1] Note: Cover averaged over all seeded sites (ie ROW, Roads, Borrow, Spoil, and Camp Sites).

* In 1984 and 1985 cover of Creeping Red and Durar Hard Fescue was combined.

** Cover based on two monitoring sites where this was seeded.

Table 1.7 Revegetation monitoring: mean percentage cover of grasses seeded in 1985[1]

Species	Mean seeded cover (%) 1985	1986
Boreal Creeping Red Fescue*	5.7	12.7
Revenue Slender Wheatgrass	4.0	4.4
Creeping Foxtail	0.4	5.1
Vantage Reed Canary Grass	0.1	1.5
Climax Timothy	3.0	3.7
Total	13.3	27.6
Kodiak Fall Rye**	2.1	0.0

[1] Note: Cover averaged over all seeded sites (ie ROW, Roads, Borrow, Spoil, and Camp Sites).

* Cover of Creeping Red and Durar Hard Fescue was combined.

** Mean based only on one monitoring site where this was seeded.

Table 1.8 Schedule of post-construction monitoring programs

PROGRAM	INITIATE	TERMINATE	FREQUENCY
STANDARD OPERATIONAL MONITORING			
- Aerial Surveillance	1984	Lifetime*	Weekly
- Ground Inspection	1984	Lifetime	Annual
GEOTECHNICAL MONITORING			
- Thaw Settlement	1984	Lifetime**	Annual
- Frost Heave	1984	Lifetime**	Quarterly
- Slope Performance	1984	Lifetime**	Eight/Year
AQUATIC MONITORING			
- Mackenzie and Great Bear	1985	Lifetime	Annual
- Others	1984	1987	Annual
RAPTOR MONITORING	1983	1987	Annual
WILDLIFE MONITORING			
- Right-of-way Monitoring	1984	1987	Continuous
- Transect Monitoring	1984	1987	Bi-annual
REVEGETATION MONITORING			
- Aerial Survey	1984	Lifetime*	Annual
- Baseline Data Collection	1984	1985	Annual
- Permanent Sample Transects	1984	1986	Annual
- Revegetation Trial Sites	1984	1986	Annual
AERIAL PHOTOGRAPHY AND GROUND TRUTHING	1986	1988	Biennial

* "Lifetime" refers to operational lifetime.
** Program may be discontinued if history of readings indicates an equilibrium situation.

2. Environmental Baseline Studies

Agency Responsible

Esso Resources Canada Limited Norman Wells, NWT.

Start-up Date

Summer 1984

Objectives

Esso Resources, on its own initiative, set up an environmental baseline and monitoring program during the summer of 1984, prior to project start-up. The intent of the study was to collect sufficient environmental data to:

1. aid environmental policy and management decisions,
2. identify and define environmental problems, and
3. measure environmental impacts.

Locations

Norman Wells

Results to Date

Water Quality

Water samples were collected in Bosworth Creek in 1984 at the IPL crossing, in the reservoir, and at the mouth. Samples were analyzed for basic water chemistry as well as the presence of selected organic chemicals, heavy metals, and inorganic chemicals.

Sediment Analysis

Sediment samples were collected at four locations in Bosworth Creek. The general physical and chemical characteristics of Bosworth Creek sediments were determined.

Fish Quality

Arctic grayling specimens were collected in the headwaters of Bosworth Creek and in Bosworth Creek reservoir in July 1984. Samples were analyzed for mixed-function-oxidase activity by the Department of Fisheries and Oceans. There seemed to be little or no difference between specimens from the headwaters of Bosworth Creek and from Bosworth Creek reservoir.

Fish specimens (9) were collected from the Mackenzie River downstream of Norman Wells in August 1985. Livers and fish muscle were analyzed for light hydrocarbons by Esso's Production Research Laboratory and the Department of Fisheries and Oceans respectively.

Air Quality

An air quality monitoring system was established utilizing 8 remote sampling stations and a sophisticated NO_2, NO_X, H_2S, and SO_2 monitoring trailer. Results are reported separately in Section 4 (Air Quality Monitoring at Norman Wells).

Vegetation Analysis

False color infra-red aerial photographs were taken during summer 1984 at a scale of 1:5000 over a 32 km strip, 16 km upwind and downwind of Norman Wells.

Soils Analysis

Surface and subsurface composite soil samples were taken at eleven stations surrounding Norman Wells in summer 1984. Basic

soil fertility, heavy metal levels, and sulfate concentrations were determined.

Noise Survey

Noise levels were surveyed around Esso facilities and at the edge of the lease nearest permanent residents. Noise levels were within acceptable limits.

Conclusions & Recommendations

Firm conclusions and recommendations are not possible due to the preliminary nature of the data collected to date. However, the data does serve to characterize environmental conditions in the area prior to oilfield expansion. The data will be used for comparison with future environmental conditions so that corrective actions can be taken as necessary.

Future Studies

Results of the baseline program will require further analysis to determine future monitoring needs. However, in general, periodic resampling for selected monitoring parameters will be conducted as necessary.

Reports Available

Dawson, C. 1985. Analysis of Fish Tissues for Light Hydrocarbon Contamination. Internal Report. Analytical and Process Technology Section, Production Research Division, Esso Resources Canada Limited.

Lund, E. 1984. Analysis of Fish Tissues for Light Hydrocarbon Contamination. Internal Report. Analytical and Process Technology Section, Production Research Division, Esso Resources Canada Limited.

Sikstrom, C.B. 1986. Scientific Permit F-85/86-05: A report dated 86 03 06.

Sikstrom, C.B. 1985. Scientific Permit F-84/85-11: A report dated 85 06 05.

Further information regarding baseline environmental monitoring results for Norman Wells is available through the Esso Norman Wells office.

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3. ISLAND MONITORING & MACKENZIE RIVER BREAKUP

Agency Responsible

Esso Resources Canada Limited

Start-up Date

Spring 1984

Objectives

1. to determine the effects of the production islands on the breakup process,
2. to confirm the stability and design adequacy of the production islands,
3. to determine maintenance requirements for the production islands and under-river pipeline systems.

Locations

Mackenzie River, between 10 km upstream and 10 km downstream of Norman Wells.

Results to Date

1. Breakup survey data for the years 1980, 81, 82, 83, and 84.
2. Geotechnical monitoring data for Dehcho Island which includes temperature and pore pressure measurements.
3. Bathymetric data showing bottom profiles and island pipeline locations in the river.

Conclusions/Recommendations

1. Breakup timing can be closely predicted.
2. Production islands have performed as expected and do not seriously affect the breakup process.
3. Production islands are stable, well designed facilities.

Future studies

1. Continued monitoring of breakup timing and Esso's predictions.
2. Periodic bathymetric surveys of the Norman Wells reach.

Reports available

Kamphuis, J.W. and J.R. Moir. 1983. Ice breakup and jamming observations along the Mackenzie River. Can. J. Civil Engineering. 10(1): 78-91.

Moir, J.R. 1979. A review of the design and impact on the river of artificial islands in the Mackenzie River at Norman Wells. Esso Resources Canada Limited, Research Department, 1PRT-2ME-7a.

Northwest Hydraulic Consultants Ltd. 1979. Regime of Mackenzie River at Norman Wells in relation to artificial island scheme. Prepared for: Esso Resources Canada Limited. 32 pp.

Northwest Hydraulic Consultants Ltd. 1981. Hydraulic Model study Norman Wells production island. Prepared for : Esso Resources Canada Limited. 17pp.

Detailed breakup and island monitoring reports are submitted to the N.W.T. Water Board annually to satisfy island monitoring requirements.

Bathymetric data may be viewed at the Esso Norman Wells office.

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4. AIR QUALITY MONITORING AT NORMAN WELLS

Agencies Responsible

Environmental Protection (Department of the Environment)
Esso Resources Canada Ltd.

Start-Up Date

1981.

Objectives

In response to an EARP Panel recommendation, Esso Resources Canada Limited and Environmental Protection commenced a joint air sampling program in the summer of 1981. The objective of the program was to determine the effect of the expansion project on selected ambient air quality parameters before, during, and after construction.

Description of sampling program: particulates and lead

As part of the joint program, Environmental Protection was to:

1. provide two high volume air samplers and all necessary accessories for their operation and maintenance,
2. install the equipment at two locations,
3. train Esso Resources staff in the operation, calibration, and maintenance of the equipment, and
4. analyze the samples and prepare a report.

Esso Resources Canada Limited was to:

1. commit staff to the project,

2. operate and maintain all equipment, and
3. collect and send samples to Environmental Protection.

Standard high volume air samplers were used for the collection of suspended particulates and the analysis of lead concentrations. Large volumes were drawn through a fabric filter, capturing particulates in the 5 to 100 micron range. Samples were collected according to the National Air Pollution Surveillance (NAPS) program sampling schedule, which called for a sample to be taken from midnight to midnight, every six days.

Description of sampling program: sulphur and nitrogen compounds

Esso's program for these parameters was divided into two sub-programs:

1. Exposure station monitoring for total sulphation and hydrogen sulphide, and
2. Continuous ambient monitoring of wind speed and direction, NO_x, NO_2, NO, H_2S, and SO_2.

Exposure station monitoring began in July 1984 and continued until April 1986 at eight stations which were located to receive maximum exposure to Esso facility emissions.

Continuous ambient monitoring occurred from July 18 to September 6, 1984, and from July 10 to September 10, 1985, and was conducted by Esso and the Western Research Division of Bow Valley Resource Services Ltd. An air monitoring trailer was set up near the Central Processing Facility and operated continuously for a three month period each summer. The scheduling of these two monitoring periods resulted in data collection before and after Central Processing Facility start-up. Sulphur dioxide and hydrogen sulphide concentrations were recorded using Monitor Labs 8850 analyzers. Nitrogen dioxide concentrations were recorded using a Monitor Labs

8840 analyzer. Wind speed and direction were recorded by an RM Young wind instrument.

Locations

The high volume sampling equipment was installed on the roof of the airport building at the east end, and on the roof of the Esso Resources Canada Limited production garage at the west end, of Norman Wells. The latter was taken out of service in 1985.

Exposure station locations and prevailing wind directions as well as the approximate locations of the air quality monitoring trailer in 1984 and 1985 are shown in Figure 4.1. The 20 year Canadian wind normals for Norman Wells were obtained from Environment Canada's meterological station at Norman Wells, and used as one of the specifications for locating the air monitoring trailer.

Results to Date

1. Air Quality Objectives

Since there are no territorial air quality standards for the N.W.T., federal standards were used where available. Federal standards have not been set for Lead, NO_x, and H_2S. For these three parameters, air quality objectives from British Columbia, Alberta, and Saskatchewan were obtained, and the most rigorous were used to produce Table 4.1 - Ambient Air Quality Objectives.

2. Total Suspended Particulates

Mean concentrations of ambient particulates for the airport station are shown in Table 4.2 and raw data are presented in Tables 4.3, 4.4, and 4.5. Insufficient data existed to provide even an estimate of

the annual values for 1982 and 1985 at the airport station. Therefore, the annual results for these years have been reported for information purposes only and should not be considered to be true mean values. Summer values were arbitrarily defined as those occuring between June 1st and September 30th.

The results are summarized as follows:

a. Average summer concentrations were between 6 and 11 times higher than average winter concentrations.
b. Average concentrations were highest during the peak of quarrying activity in 1982 and although they have been steadily declining since 1982, the values remained high until the end of construction.
c. During the summer, concentrations exceeded the Environment Canada acceptable 24 hour limit of 120 ug/m^3 75% of the time in 1982, down to 13% of the time in 1985.

3. Lead

From the third annual report, the results for lead indicated no major impacts, and therefore lead concentrations were not considered in great detail for this report. As a point of information, the maximum lead concentration in 1985 was 0.10 ug/m^3 and 15 of the 22 samples analyzed contained no lead (ie. less that 0.005 ug/m^3). Raw data for lead concentrations from 1981 to 1985 are presented in Tables 4.3, 4.4, and 4.5.

4. H_2S, NO, NO_2, NO_x, and SO_2

Exposure station monitoring results for the period August 1984 through April 1986 are shown in Figure 4.2 for hydrogen sulphide and Figure 4.3 for total sulphation as sulphate equivalents. All measured parameters were at least one order of magnitude lower than

Alberta standards. Measurable amounts were attributable to local sources. The H_2S readings were attributed to the Battery 3 flare pit, and the now abandoned refinery heavy fuel oil flare. All observed NO_x readings were attributed to vehicular traffic, except on the infrequent occasions when northerly winds caused the measurement of emissions from the four-cylinder diesel generator used to power the air quality monitoring trailer.

Detailed results of the ambient air quality monitoring conducted in 1984 and 1985 are available for viewing at the Esso Norman Wells production office. A summary of these results is provided in Tables 4.6, 4.7, 4.8, 4.9, and 4.10. No levels which would exceed the objectives in Table 4.1 were encountered. All measured levels were an order of magnitude below common standards.

Conclusions

1. Start-up and operation of the new Central Processing Facility at Norman Wells had only minor localized effects on ambient levels of hydrogen sulphide, nitrogen oxides, or sulphur oxides in the Norman Wells area.

2. Measured levels of common air pollution parameters were too low and infrequent to attribute emissions to any particular source.

3. After the quarrying activity ceased, the major contributor to particulate concentrations in Norman Wells seemed to be vehicular traffic on the gravel roads. This would explain the much lower values in winter when the road surfaces are frozen.

4. Construction was essentially complete by the end of 1984, and this is reflected in the lower particulate concentrations which occurred in 1985. Particulate generation would appear to be a

concern only during quarrying or trucking activities on gravel roads.

Recommendations

1. Air quality monitoring programs for future hydrocarbon developments should be realistically designed with appropriate consideration of industry activities in relation to their possible impact on communities or sensitive environmental areas.

2. The application of Alberta environmental standards and protocols should be considered for determining acceptable air quality methods and standardizing reporting requirements in the Northwest Territories.

3. To reduce the effects of construction activity on ambient air quality, appropriate dust suppression measures should be implemented.

Future Studies

The high volume sampler at the airport has been incorporated as a station in the NAPS program and is being jointly operated by Environmental Protection and the Atmospheric Environment Service. Results for particulates and lead will be available in future editions of Environment Canada's "Annual NAPS Summary".

Since no air quality concerns were identified, exposure station and ambient air quality monitoring have been discontinued. However, Alberta air quality models will be run for the Norman Wells facility so that the predicted results can be compared with the results of Esso's monitoring program.

Reports Available

Environment Canada. November 1976. Criteria for National Air Quality Objectives, Federal-Provincial Committee on Air Pollution.

Environment Canada. December 1986. Norman Wells NAPS Station Results for 1985.

Esso Resources Canada Limited. July 1985, November 1985. Summary Reports on the Exposure Station Monitoring Program submitted to Environmental Protection Service. Detailed results of the ambient air quality monitoring program are available for viewing at Esso's Norman Wells Production Office.

Federal Environmental Assessment Review Office. January 1981. Report of the Environmental Assessment Panel on the Norman Wells Oilfield Development and Pipeline Project.

Touzin, M. 1984. Air Quality Monitoring at Norman Wells July 18 to September 1984. Unpublished report. Production Research Department, Esso Resources Canada Limited,

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Figure 4.1 Locations of Norman Wells air quality monitor exposure stations (1 - 8)

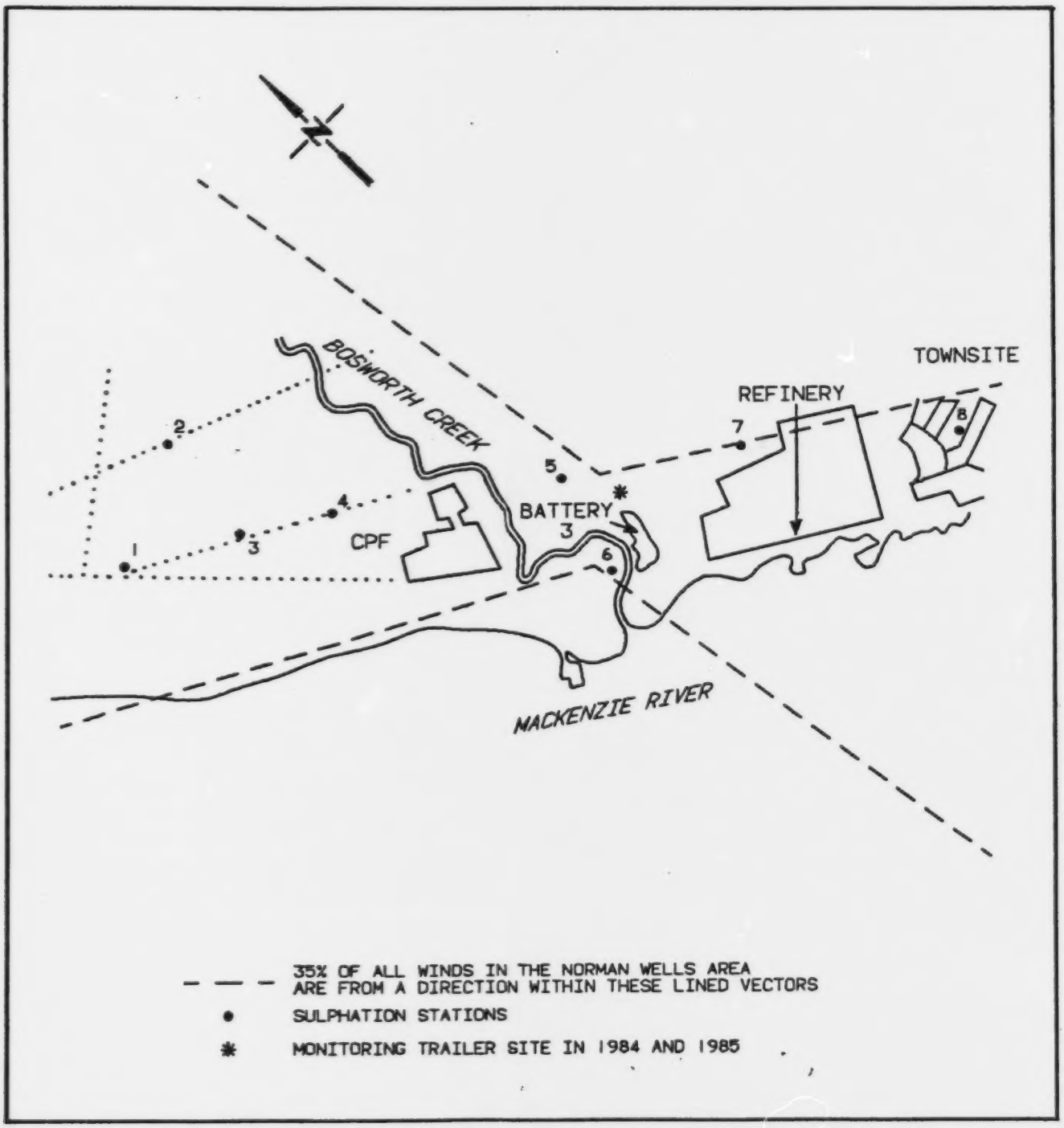

Figure 4.2 Hydrogen sulfide (mg SO_3/day/100 cm^2) at Norman Wells N.W.T. for eight exposure stations during the period of August 1984 to March 1986

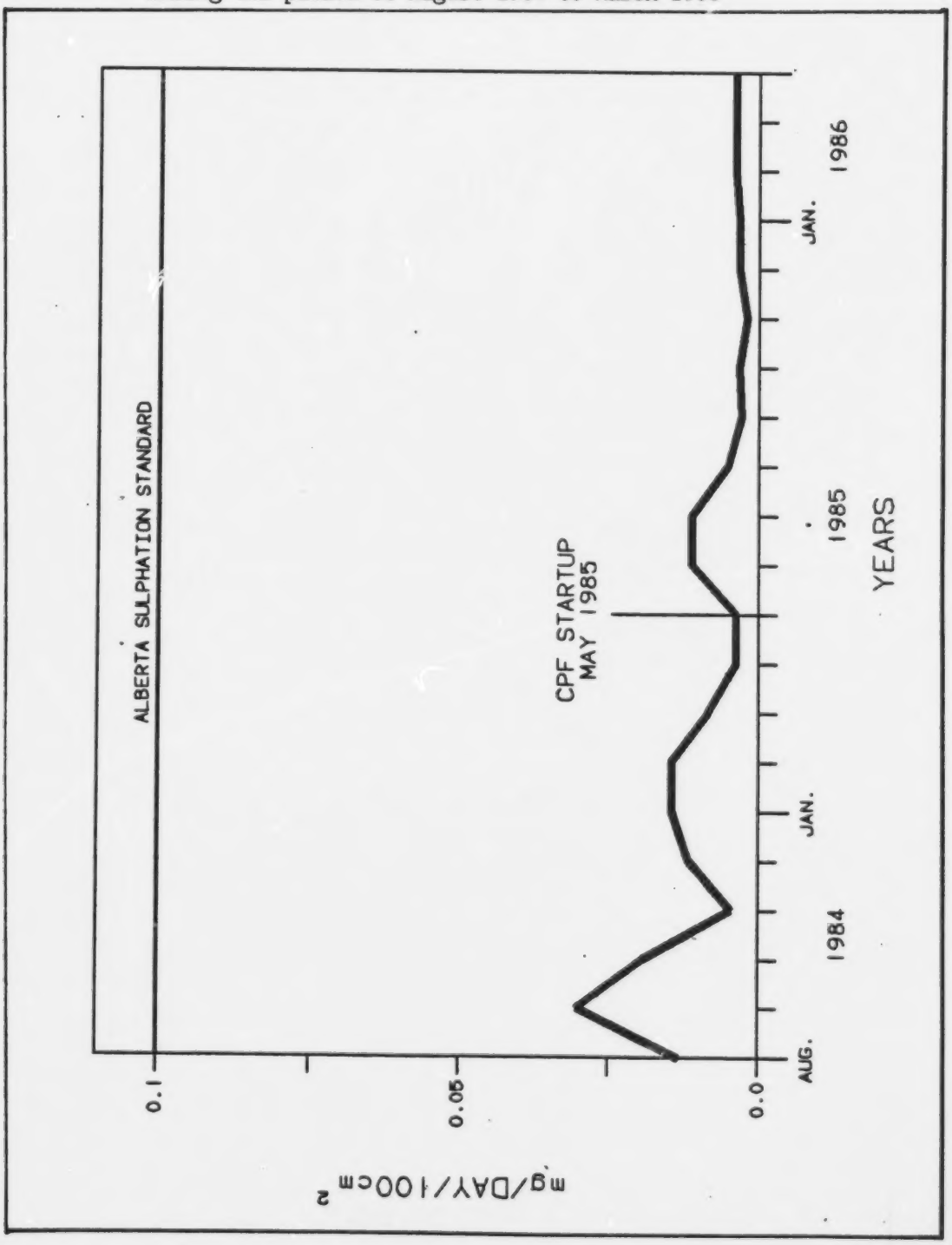

Figure 4.3 Total sulphation (mg SO_3/day/100 cm^2) at Norman Wells N.W.T. for eight exposure stations during the period of August 1984 to March 1986

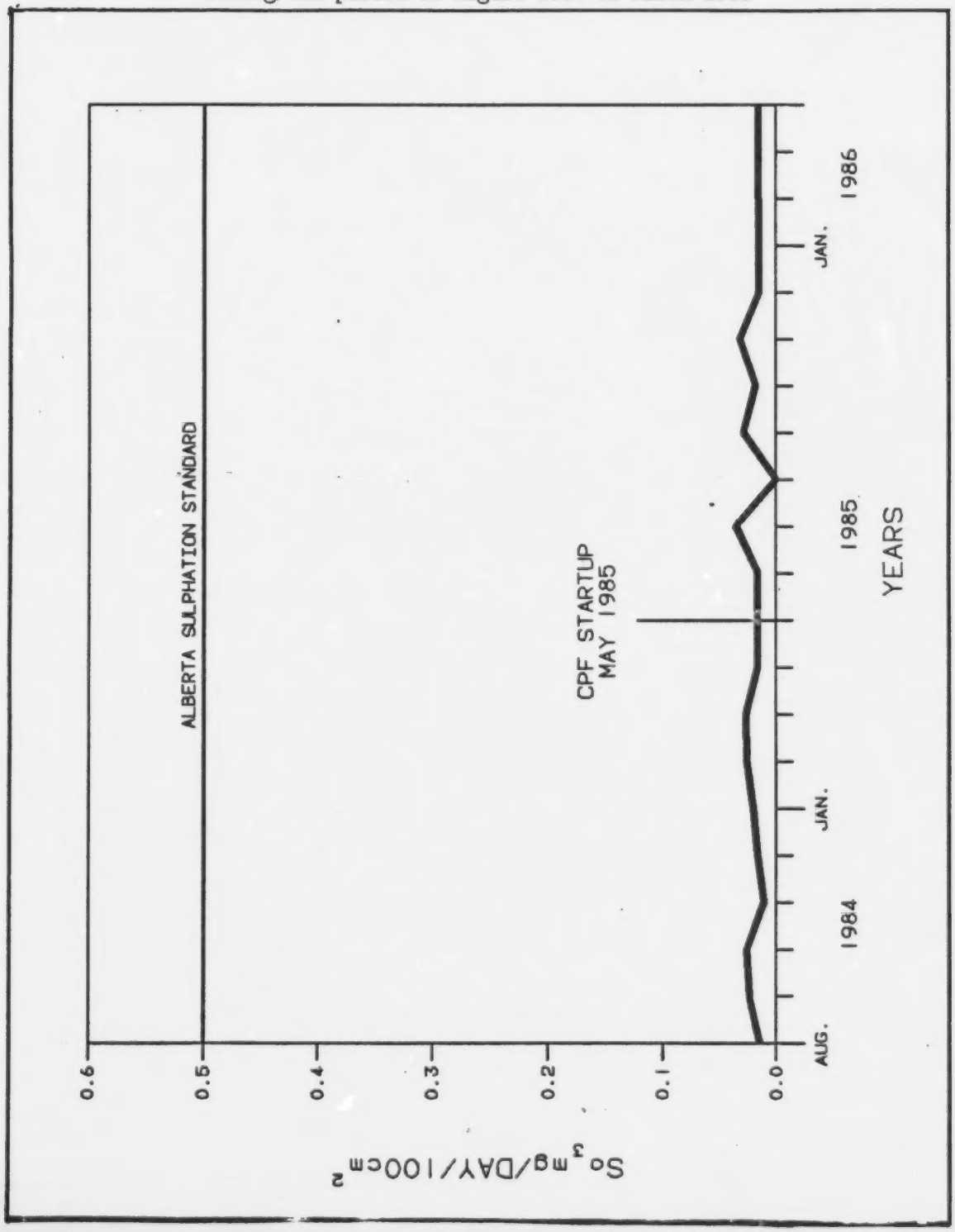

Table 4.1

Ambient air quality objectives

Parameters	Units	Jurisdiction	Time Period	Concentrations Maximum Desirable	Concentrations Minimum Acceptable
TSP	ug/m^3	Federal	Annual mean	60	70
			Max. 24 hour		120
Pb	ug/m^3	B.C.	Annual mean		2
			Max. 24 hour		4
NO_2	ug/m^3	Federal	Annual mean	60	100
			Max. 24 hour		120
NO_x (as NO_2)	ug/m^3	Alberta	Annual mean		60
			Max. 24 hour		200
H_2S	ug/m^3	B.C.	Max. 24 hour		4
			Max. 1 hour		7.5
H_2S	$mgSO_3/100cm^2$	Alberta	Max. 24 hour		0.1
SO_2	ug/m^3	Federal	Annual mean	30	60
			Max. 24 hour	150	300
			Max. 1 hour	450	900
TOTAL SULPHATION	$mgSO_3/100cm^2$	Alberta	Max. 24 hour		0.5

Table 4.2 Total suspended particulate data
airport station, Norman Wells, NWT
all concentrations in ug/m³

YEAR	1981	1982	1983	1984	1985
WINTER					
No. of samples	9	3	11	14	6
Low	5	5	9	5	47
High	20	74	57	94	147
Average	12	*	18	16	*
% above 120	0	*	0	0	*
SUMMER					
No. of samples	17	16	9	13	16
Low	20	19	19	8	19
High	295	295	224	244	196
Average	129	172	126	101	65
% above 120	41	75	56	38	13
ANNUAL					
No. of samples	26	19	20	27	22
Average	71	*	67	54	*
% above 120	27	*	25	19	*

* Insufficient Data

Table 4.3 High volume sampler results
airport station, Norman Wells, NWT

Date	Particulates ug/m³	Lead ug/m³	Date	Particulates ug/m³	Lead ug/m³
1981			1982		
June 15	87	0.04	Jan 5	13	0.08
21	63	0.05	Apr 29	74	0.11
27	39	0.06	June 29	260	0.09
July 2	20	<0.03	July 4	194	0.06
9	57	0.05	10	68	0.06
15	177	0.07	16	158	0.05
21	33	<0.03	22	250	0.08
27	52	<0.03	28	192	0.10
Aug 2	148	<0.03	Aug 3	232	0.06
8	295	0.13	9	295	0.08
14	125	0.07	15	287	0.09
20	141	0.08	21	49	0.06
26	219	0.09	28	249	0.05
Sept 1	21	0.04	Sept 2	19	0.09
7	76	0.04	8	151	0.05
19	158	<0.03	14	196	0.13
25	28	<0.03	21	189	0.08
Oct 1	---	<0.03	26	50	0.05
7	8	<0.03	Oct 2	5	0.03
13	17	0.06			
19	20	<0.03			
25	14	0.05			
31	12	<0.03			
Nov 7	13	0.04			
12	8	0.04			
18	5	<0.03			
Dec 6	7	<0.03			
12	---	0.06			
19	---	<0.03			
24	---	<0.03			
30	---	<0.03			

Table 4.4 High volume sampler results
airport station, Norman Wells, NWT

Date	Particulates ug/m³	Lead ug/m³	Date	Particulates ug/m³	Lead ug/m³
1983			1984		
June 5	66	0.00	Jan 17	94	0.15
17	94	0.05	Feb 18	9	0.14
23	153	0.02	24	33	0.15
29	224	0.06	June 23	141	0.10
Aug 10	19	0.02	July 5	164	0.10
16	54	0.06	11	8	0.10
28	169	0.05	17	33	0.10
Sept 9	179	0.07	23	54	0.00
15	174	0.04	Aug 4	54	0.10
Oct 9	11	0.03	10	69	0.00
15	57	0.03	16	33	0.01
21	29	0.08	22	186	0.01
27	12	0.17	Sept 9	8	0.00
Nov 2	9	0.06	15	239	0.00
8	13	0.00	21	75	0.10
14	11	0.15	27	244	0.20
20	10	0.02	Oct 9	7	0.10
Dec 8	20	0.40	15	8	0.10
20	11	0.32	21	5	0.10
26	14	0.01	Nov 14	8	0.20
			20	7	0.00
			26	7	0.20
			Dec 2	5	0.10
			8	9	0.10
			14	9	0.20
			20	11	0.40
			26	9	0.30

Table 4.5

High volume sampler results
airport station, Norman Wells, NWT

Date		Particulates ug/m³	Lead ug/m³
1985			
April	1	47	0.10
May	1	60	0.10
	7	48	0.00
	13	115	0.10
	19	147	0.00
	25	120	0.00
June	6	51	0.00
	18	64	0.00
	24	184	0.00
	30	94	0.00
July	6	27	0.00
	12	70	0.00
	18	60	0.00
	30	38	0.00
Aug	11	33	0.00
	17	19	0.00
	23	24	0.10
	29	196	0.10
Sept	4	28	0.10
	10	28	0.00
	22	55	0.00
	28	76	0.10

Table 4.6 H_2S monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range (ppb H_2S)				Monthly Average ppb
		0 - 3	4 - 10	11 - 50	>50	
July 1984	319	99.4	0.6	0.0	0.0	0.0
Aug. 1984	701	99.4	0.6	0.0	0.0	0.0
Sept. 1984	122	100.0	0.0	0.0	0.0	0.0
					Annual Average	0.0
July 1985	28	100.0	0.0	0.0	0.0	0.1
Aug. 1985	54	100.0	0.0	0.0	0.0	0.1
Sept. 1985	23	100.0	0.0	0.0	0.0	0.1
					Annual Average	0.1

Table 4.7 SO_2 monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range (ppm SO_2)					SO_2 ppm Monthly Average
		.00 -.02	.03 -.06	.07 -.17	.18 -.34	>.34	
July 1984	339	100.0	0.0	0.0	0.0	0.0	0.0
Aug. 1984	727	100.0	0.0	0.0	0.0	0.0	0.0
Sept. 1984	130	100.0	0.0	0.0	0.0	0.0	0.0
					Annual Average		0.0
July 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
Aug. 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
Sept. 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
					Annual Average		0.0

Table 4.8 NO_2 monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range ($ppm\ NO_2$) .00 -.11	.12 -.21	>.21	NO_2 ppm Monthly Average
July 1984	357	100.0	0.0	0.0	.001
Aug. 1984	739	100.0	0.0	0.0	.001
Sept. 1984	129	100.0	0.0	0.0	.002
			Annual Average		.001
July 1985	41	100.0	0.0	0.0	.001
Aug. 1985	23	100.0	0.0	0.0	.000
Sept. 1985	0	100.0	0.0	0.0	.000
			Annual Average		.000

Table 4.9 NO monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984

Date	Number of Readings	% Readings in concentration range (ppm NO) <.11	.12 - .21	>.21	Monthly Average
July 1984	357	100.0	0.0	0.0	.002
Aug. 1984	739	100.0	0.0	0.0	.001
Sept. 1984	129	100.0	0.0	0.0	.002
			Annual Average		.002

Table 4.10 NO_X monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984

Date	Number of Readings	% Readings in concentration range (ppm NO_x) <.11	.12 - .21	>.21	Monthly Average
July 1984	357	100.0	0.0	0.0	.003
Aug. 1984	738	100.0	0.0	0.0	.002
Sept. 1984	129	100.0	0.0	0.0	.004
				Annual Average	.003

5. TERRAIN PERFORMANCE

Agencies Responsible

Geological Survey of Canada and Terrain Sciences Division, Department of Energy Mines and Resources, in cooperation with Department of Indian Affairs and Northern Development, National Research Council of Canada, Agriculture Canada, and Interprovincial Pipe Line (NW) Ltd.

Start-up Date

August 1983

Objectives

This research program is directed toward the observation and prediction of geomorphic and geologic conditions along the Norman Wells to Zama pipeline route. Particular attention is focused upon the distribution of surficial materials, including ground ice, and the relationship to terrain performance during pipeline construction and operation. Specific project objectives are:

1. to determine the nature of geomorphic and geologic factors influencing terrain performance along the pipeline right-of-way,

2. to evaluate predicted and actual terrain impacts with respect to mitigative measures employed on the pipeline project, and

3. to evaluate the concept of northern terrain sensitivity in relation to pipeline construction and operation.

Location

The project objectives relate to the pipeline right-of-way between Norman Wells, N.W.T. and Zama, Alberta.

Results to Date

First Year (1983) Observations and Results

Approximately 100 sampling sites were established along the pipeline right-of-way between Norman Wells and Zama to assess three factors: 1) climate (and particularly ground temperature), 2) geomorphic environment, and 3) geologic environment. Data were collected by means of bore hole logs, instrumented bore holes, ditch logs, field monitoring of slope cuts, ditch walls and related observations during construction, and aerial photographs.

Climatic Conditions

The Mackenzie Valley and northern Alberta experienced an extremely wet and cool summer in 1984. Precipitation as recorded in Norman Wells, Fort Simpson, and High Level was as much as 240% above normal. Much of this precipitation occurred in separate storm events.

Increased runoff resulted in:

1. saturation in near-surface sediments for prolonged periods, with ponding in closed basins,
2. high discharge levels in streams and rivers with high sediment loads and river bank erosion,
3. possible raised ground water tables in karst areas, and
4. possible decreased stability of both natural and pipeline related slopes.

Preliminary observations were carried out on construction spreads 1, 4 and 6. Fieldwork proceeded as follows:

April 27 - May 1	Km 1-140, 478-526, 550-801
June 5 - 7	Km 0-150
September 17 - 27	Km 0-848

Terrain Performance

Right-of-Way Conditions:

1. With a few notable exceptions, there was little evidence of subsidence or erosion along the right-of-way. Slopes and side cuts generally appeared to be performing well.
2. Locally, settlement occurred along the ditchline in areas where ice-rich or snow-contaminated backfill was used. On level stretches of the right-of-way, this resulted in water ponding within shallow linear basins.
3. Observations indicated that the organic mat was disturbed by winter grading operations over approximately 15-25% of the right-of-way between kms 0-70. To date, this does not appear to have contributed to adverse terrain performance.

Areas of Erosion/Slope Failure:

1. Localized erosion and/or slope instability conditions developed at a number of sites on the pipeline right-of-way, most notably at km 67 (Norman Range), km 78 (Great Bear River N.), km 168 (Seagram Creek S.), and km 732 (Kakisa River S.)
2. In most cases, adverse terrain performance appeared due to a combination of unexpectedly high surface runoff and misplacement of erosion control structures.

Mitigation and Maintenance:

1. Along 99% of the pipeline route constructed in 1984, mitigative measures performed well in reducing terrain impact. In the few

areas where they were less successful, the problem appeared to relate to field implementation rather than to the validity of the design concept.

2. Woodchip-covered slopes appeared to be performing well, although at some sites differential settlement of the woodchip surface had occurred, requiring periodic maintenance.
3. Erosion control berms were prone to wash-out in the spring as a result of the high rate of sandbag deterioration. It was expected that this potential problem could be substantially mitigated by the stabilizing effect of revegetation.
4. Temporary maintenance work was carried out during the summer to stabilize areas of erosion and slope instability. This work consisted primarily of sandbag berm replacement. Other activities included the excavation of a temporary drainage ditch at km 67 and the placement of concrete blocks to check riverbank erosion at Seagram Creek (km 168).

Second Year (1984) Observations and Results

Some fieldwork was undertaken during the 1984/85 construction season to examine the surficial geology exposed in slope and ditch sections on Spread 3.

1985 Observations and Results

Particular attention during summer field excursions was focused upon:

1. observation of physical condition of right-of-way surface,
2. observations of terrain stability on slopes and at stream and river crossings,
3. identification of actual and potential zones of enhanced erosion,
4. measurement of near-surface ground thermal regime along transects across the right-of-way, and

5. analysis and interpretation of detailed ground surface survey data.

(Note: Components (4) and (5) were carried out in association with Earth Physics Branch permafrost and terrain monitoring and DIAND revegetation monitoring programs.)

Climatic Conditions

In contrast to 1984, winter snowfall in the Mackenzie Valley was significantly above normal in January and February, with snowfall greater than twice normal values recorded at Fort Simpson. This provided a good base for construction activities. Summer air temperatures were predominantly below normal, with monthly means 0.5 to 2.5 degrees lower than average. This resulted in the development of shallower active layers at many sites in comparison to 1984 observations. Summer precipitation was also near or slightly below normal, particularly in the southern Mackenzie Valley and northern Alberta. This factor probably accounts, in part, for the reduced incidence of early summer surface erosion on the right-of-way. However, as in 1984, some erosion events occurred which may be related to storm periods, characterized by relatively brief but intensive precipitation.

Terrain Performance

A. 1985 Construction spreads

In general, right-of-way terrain performance during the post-construction thaw season was similar to that observed the previous year on 1984 construction spreads. Specific comments are as follows:

1. Local settlement again occurred along the ditchline in areas where ice-rich or loose, blocky backfill was used. However, the incidence of this condition was reduced by the emplacement of a larger and more accurately positioned berm during 1985 winter construction.

2. Surface erosion occurred at a number of locations in summer 1985, although both frequency and magnitude of erosion events were significantly less than in 1984. This probably reflects a combination of factors, including lower than average summer precipitation and therefore reduced runoff levels. However, it also reflects the prompt and effective summer maintenance work undertaken by IPL.

3. Erosion was most pronounced along segments of right-of-way traversing long, low-angle slopes, for example on the south side of Redknife Hills, rather than on steep slopes or at river crossings. In many cases, flow was concentrated along stretches of subsided ditchline which provided a natural route for water movement.

4. Erosion of woodchips occurred on the north side of the Blackwater River as a result of runoff from a steep side slope. It should be emphasized, however, that woodchips mobilized by the flow were redeposited at distances of 0-200 m from the right-of-way and did not enter any adjacent water courses.

5. Most slopes appeared stable following the first thaw season. A small mass flow was observed on the north bank of Jean Marie Creek, and appeared to have resulted from the saturation and mobilization of sediments by water percolating along the ditchline.

6. Summer maintenance activities on 1985 construction spreads included site specific restoration of eroded areas, together with a systematic program to refill and reroach areas of subsided ditch.

B. 1984 Construction spreads

In general, terrain appeared to have stabilized along most segments of the 1984 construction spreads, and revegetation was well advanced. Specific points are as follows:

1. Comparison of surveys made at EMR monitoring sites in summer 1984 and 1985 suggested that up to 1 m of settlement occurred in areas underlain by ice-rich surficial sediments (eg. EMR 84-1, EMR 84-3a). Sites underlain by thaw stable materials experienced little surface change (eg. EMR 84-3b).

2. Further geomorphic evidence of localized ground surface subsidence was provided by the development of hummocky thermokarst terrain (eg. KmP 78) or small, near-circular thaw ponds (eg. KmP 80).

3. Major remedial work was undertaken during winter 1985 at sites of 1984 erosion and in particular at km 67 and km 78 (north side of Great Bear River). These sites now appear completely stable and well protected from erosion.

C. Summary

Terrain conditions have now been monitored over one thaw season following construction on spreads 2, 3 and 5, and over two full thaw seasons on other spreads. Sub-optimal terrain performance has been limited to less than 1% of the total pipeline route.

1986 Observations and Results

A single period of fieldwork was undertaken in 1986, from June 19-23. A second field visit, scheduled for September, was cancelled. During the June trip, the right-of-way was inspected by helicopter between Kmp 0 (Norman Wells) and Kmp 818 (south of Pettitot River). Approximately 40 stops were made to read IPL/EMR/INAC instrumentation, to measure near-surface thermal transects, and to make general observations of right-of-way terrain conditions and performance.

These observations relate only to the early phase of the 1986 thaw season. Additional information on terrain conditions later in the summer has, however, been made available to this project by other members of the research group, and in particular by K.L. MacInnes, (INAC), M. Burgess (EMR), C. Tarnocai (Agriculture Canada), and T.H.W. Baker (NRC).

Climatic Conditions

The following comments are based upon the analysis of May-August meterological data from Atmospheric Environment Service weather stations at Norman Wells, Fort Simpson, High Level, Fort Norman and Wrigley. Additional observations from several Forestry fire towers have been made available by INAC.

Air temperature were near normal in the Mackenzie Valley in May, June, and July. Temperatures were below normal in August, by as much as 4.0 C in the Fort Simpson area. Total monthly precipitation was also near or below normal at most stations, and well below normal in the Norman Wells area in June and July. As in previous years, much of the precipitation occurred during storm events which were often very localized in their effect. For example, the Mount Gaudet fire

tower recorded nearly 80 mm of rainfall within a 48 hour period from June 24-25. This exceeds any recorded summer storm event in 1984 or 1985.

Terrain Performance

General Right-of-way condition (June 1986):

1. Most of the right-of-way appeared to be in good condition during the June monitoring trip. No instances of exposed pipe, major erosion or slope movement were observed.
2. Some right-of-way segments are still characterized by a subsided ditchline, in some cases containing ponded water. IPL is continuing a program to rebuild the roach in these areas. Subsided ditch was also noted across several stream floodplains.
3. In most cases, remedial work implemented during the previous winter appeared to have successfully corrected problems identified in 1985. One exception is on the slope north of Blackwater River (Kmp 224), where there is evidence of continued woodchip erosion and mass movement on the west side slope.

Surface Erosion:

1. Few instances of surface erosion were observed during the June monitoring trip. This reflects both low precipitation levels from May to early June and also the successful implementation of erosion control measures by IPL. As in 1985, surface erosion again occurred on gently sloping terrain south of Fort Simpson (Kmp 654-657) as a result of water flowing along the ditch. Cross drainage also resulted in shallow (<30 cm) gullying, for example at Canyon Creek South (Kmp 19), Norman Range (Kmp 65), and IPL Slope 73 North (Kmp 270). Gullying up to 2 m in depth developed on the shoofly adjacent to IPL Slope 75 (Kmp 2873), over a distance of approximately 20 m.
2. At several stream crossings, approach slopes were eroded by

floodwaters related to the break-up of ice dams or heavy precipitation events in late June, July, and August. High water levels resulted in the flotation and erosion of woodchips at Unnamed Creek North (Kmp 133). This has undermined the wooden crib structure, resulting in further slumping and loss of woodchips.

3. During a major rainstorm on June 24-25, the Hodgson Creek catchment north of Wrigley received nearly 80 mm of precipitation within a 48 hour period. High runoff levels resulted in riverbank erosion both upstream and downstream of the pipeline crossing (Kmp 305), and the reactivation of several abandoned stream channels. Following the flood, the river appeared to have changed its channel pattern, such that part of its flow was initially directed across and along the right-of-way for a distance of approximately 300 m from the original crossing point. This caused some erosion of the ditchline and right-of-way. Sandbags were used as a temporary remedial measure to retrain water across the right-of-way.

Surface Stability:

1. Surface subsidence has been noted at a number of localities, including the right-of-way between EMR thermal fences 85-7B and 85-7C, and an adjacent shoofly. These sites are being monitored by means of visual observation and topographic survey.
2. Topographic surveys were undertaken in September 1986 at all EMR monitoring sites within the N.W.T. These data are currently being analyzed, and will be used to evaluate surface stability at these sites.

Future studies

Terrain performance research and monitoring will be continued for at least two more years in order to assess long-term terrain stability

in relation to an operating northern pipeline. Fieldwork will be undertaken at the beginning and end of each thaw season.

Reports available

Harry, D.G. 1984. Norman Wells to Zama Pipeline: Project to Monitor Terrain Performance Progress Report, November 1984. Unpubl. Rept. Terrain Sciences Division, Geological Survey of Canada. 4pp.

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6. THERMAL REGIME AND GROUND STABILITY

Agencies Responsible

Permafrost Research Section (formerly part of Earth Physics Branch), Geological survey of Canada, Terrain Sciences Division, Department of Energy, Mines and Resources, in cooperation with Department of Indian Affairs and Northern Development, National Research Council of Canada, Agriculture Canada, and Interprovincial Pipe Line (NW) Ltd.

Start-Up Date

1983.

Objectives

1. to monitor both short and long term changes in the active and permafrost layers and the stability of permafrost in the alignment area in relation to development and natural climatic change,
2. to assess the thermal and ground disturbances caused by pipeline installation and operation,
3. to evaluate the effectiveness of mitigation and restoration procedures used on the right-of-way, and
4. to identify improvements which might be made in the construction, operation, and monitoring of future northern pipelines, with special reference to assessment of environmental impact including alignment selection, ground surface protection, land stabilization, and restoration.

Locations

See Table 6.1 and Figure 6.1

Results to Date

Six monitoring sites were established during the 1983/84 construction season. An additional seven sites were established during the 1984/85 construction season with temperature cable installation completed by the end of March 1985. At these locations (Figure 6.1) the pipeline traverses particularly sensitive permafrost, ground ice and terrain conditions, or interfaces between different terrain units (Table 6.1). The basic long term (10 years) monitoring program includes monthly site visits. Remote locations were equipped with automated data acquisition systems and require less frequent site visits.

One ground probing radar survey was conducted in May 1985. Time Domain Reflectometry (TDR) rod installation was completed in October 1985. A TDR survey of the 1984 sites was done in May and another of all sites in October. A ground surface elevation survey was obtained in May for the 1985 sites and several 1984 sites. In September, selected sites were resurveyed. In collaboration with the Atmospheric Environment Service (Environment Canada), a micrometeorological station was set up in March at the Canyon Creek site.

The data collected from all the preceding surveys have yielded information on the following:

1. thermal regime on and off the pipeline right-of-way (ROW), in particular, the effects of snow clearance during construction, pipeline trenching, water ponding, woodchip insulation, snow

distribution, and differential active layer development. (See Figures 6.2 to 6.5).

2. distribution and redistribution of water both on and off the ROW, within and below the active layer, and the associated changes in soil electrical characteristics.

3. variation of the active layer both with time and along continuous profiles across the ROW (see Figure 6.6).

4. terrain heave and settlement at the monitoring sites.

Thermal data at the 1984 sites is now sufficient to define an annual ground temperature envelope. This envelope provides a baseline which can be used to evaluate future thermal changes. At the 1985 sites, thermal data covering 2/3 of an annual cycle have been acquired to date. Even with this partial envelope, many interesting features have been observed.

Activities - Late 1985 and 1986:

1. Data collection

Monthly site visits to collect ground temperature data continued throughout the year for all sites, as described in Tables 6.1, and 6.2 and Figures 6.2 and 6.7, except the remote locations of Table Mountain, Redknife Hills and Petitot River (north and south). In June, ground probing radar surveys were conducted at the Great Bear monitoring sites. Downhole electrical conductivity measurements were also carried out in June using the geophysical holes at Pump station 1, Canyon Creek (A, B and C) and Great Bear (A and B). TDR measurements were taken at all sites both in May and in October. In September, all fences in the N.W.T. were resurveyed.

2. New instrumentation

In March 1986, a drilling program was undertaken at the Table Mountain sites to establish new off-ROW reference holes at each of the three fences. Three new holes were drilled in an attempt to achieve less off-ROW ground surface disturbance than had occurred during the 1985 drilling. The new hole at fence A was deepened to 93 m to provide a reference for long term climatic changes in this area of the Mackenzie Valley.

In August, shallow 1.5 m soil temperature probes were installed at 13 fences, both on and off the right-of-way, as part of a new project undertaken in cooperation with Agriculture Canada (Table 6.3). Permanent snow depth stakes were installed in August and September. In September, additional instrumentation was installed on the woodchip slope fence at Canyon Creek B, as part of a new project in cooperation with the National Research Council, to evaluate wood chip insulation.

In the fall of 1986, four IPL thaw settlement sites were instrumented with pairs of 10 m temperature cables. Two of these sites overlap with existing fences (km 272.0 and 608) and two are at new locations (km 135.1 and 469.7). An additional site (km 95.1) was instrumented with one cable. The instrumentation was undertaken in cooperation with IPL in conjunction with their drilling program at thaw settlement monitoring sites.

In October, a fifth automatic data acquisition system was installed at Petitot River North B to ensure that a continuous annual record was obtained in one of the remote peat plateau sites in northern Alberta. This fence now joins Table Mountain A and B, Great Bear A and Canyon Creek A on the list of sites with an automatic system. These loggers are connected to the ground temperature cables (and to

the soil probes at three fences as well) but not to the pipe temperature sensors.

3. IPL remedial work at instrumented fences

Winter remedial work was carried out by IPL in February and March 1986 near several instrumented fences. Additions to erosion control berms were made at Canyon Creek C and new select backfill was added to the trenches at Manner's Creek C and Moraine South. In organic areas, organic surface material adjacent to the trench was bladed into and over the trench during March 1985 and late summer 1985.

Brief Climatic Perspective (winter 85/86 based on AES records at Norman Wells and Fort Simpson)

Early snowfall (October-November 1985) was higher than in the previous winter, while later snowfalls (January and February) were lower. Winter mean monthly temperatures were colder than normal in October, November, January, February and April, and warmer than normal in December and March. For summer 1986 conditions see summary in Section 5 (Terrain Performance).

Results to Date

Two years of temperature data have been collected at the 1984 fences, enabling two annual ground temperature envelopes to be defined. A baseline ground temperature envelope can be defined at the 1985 sites, where 18 months of data has now been collected. Thermal changes resulting from right-of-way widening and clearance, tree removal and ground surface grading, pipeline construction and trenching are apparent. Only 18 months of temperature data has been collected since the opening of the pipeline, however the thermal performance to date of an ambient temperature pipeline can begin to be assessed. This is a limited data base, from a thermal and terrain

stability view point, from which to begin addressing the preparation of environmental guidelines for future northern pipelines. Nevertheless, observations can begin to be compared to the early and general thermal, active layer, and thaw settlement predictions of the Environmental Impact Statement and National Energy Board applications.

Some highlights of analyses and observations through to October 1986 are reported below. Most "end of 1986" thaw season analyses are still underway.

1. Pipeline Temperatures:

A comparison of pipe temperatures and ground temperatures at a depth of 1 m on the ROW (at all EMR/INAC fences instrumented with pipe temperature sensors) is now underway to determine whether the pipeline is behaving as an ambient temperature line (i.e. to examine the prediction that pipe temperatures will closely follow the temperatures of the surrounding soil).

An examination of the pipe temperature data at individual fences or small groups of fences shows that:

a. Data from Canyon Creek A, B, and C
   Prior to oil filling the line, temperatures of the pipe and of the surrounding soil at each fence were in close agreement (within 1 degree) and pipe temperatures were distinct from one fence to the next. After oil flow, pipe temperatures at each fence no longer closely followed their respective soil temperatures (differences of up to 4 degrees) and pipe temperatures were similar at each fence.

b. Since oil flow, all fences from km 477 south to km 818, whether

permafrost or non-permafrost, clearly have shown a mean annual pipe temperature above 0° C. In fact, at many of these fences (9, 10A, 10B, 11 12A, 12B; and likely 5A, 5B, and 6, although no mid-winter data were collected at the last three fences) pipe temperatures were positive throughout the last year.

c. Pipe temperatures in the northern section from site 84-1 to 85-7C (km 272), where permafrost underlies 75% of the terrain, appeared to be averaging around 0° C on an annual basis since oil flow.

d. Since oil flow, the pipe temperatures have consistently risen by 2 to 3° C from fence 9 to fence 10A (Mackenzie Highway South), a distance of only 5 km. Pump Station 3 is located between these two sites. The highest pipe temperatures of all the sites have usually been recorded at the Mackenzie Highway South fences (temperatures of up to 10° C were recorded in the summer of 1986).

2. Terrain Stability:

a. Surface topography changes across the ROW (not only at the trench) have become apparent at several southern permafrost sites. A wide swath of relative settlement has formed on either side of the trench, covering a total width of approximately 10 m and often skewed to the spoil side (fences 6, 5A, 5B, 13A, 13B, 12B, 10B, 8C, and 8B). These changes likely resulted from differential active layer deepening and thaw subsidence across the ROW; in addition, at some organic sites, this area was bladed for trench re-roaching.

b. Uneven (sometimes undulating) surfaces and tension cracks have appeared on several woodchip slopes; these suggest either differential settlement in the chips or in the soil beneath.

Differential snow melt observed on many woodchip slopes in October 1986 suggests differential heating (decomposition) in the pile.

3. Changes in Permafrost Depth:

The thin permafrost (less than 4 m) originally noted at fence 10B (new clearing) and fence 11 (recent helipad clearing) has now disappeared on the right-of-way.

Future Studies

The project is a long term study with an anticipated life span of 10 years or until conditions stabilize. Some aspects of the project may be adjusted to respond to changing surface conditions and information requirements.

Monthly acquisition of ground temperatures and regular collection of related data (active layer transects, TDR, surface surveys, snowdepths, etc.) will continue throughout 1987. The use of automatic data loggers, which can be left unattended gathering ground temperature data in the field for six months, will likely increase in the next few years.

Laboratory investigations of the physical, thermal, and electrical properties of the continuous cores collected in the geophysical holes have begun and will continue in the next year. As the temperature and material properties data bases expand, simulations and predictions of the ground thermal regime at the study sites will begin.

Several geophysical techniques may be used in the coming years. These include:

1. further ground probing radar surveys and an automated self potential and vertical sounding system to follow active layer development,
2. transient electromagnetic soundings to study the base of permafrost, and,
3. in the geophysical access holes, neutron probes and an experimental resonance capacitance meter to obtain water distribution profiles to depths of up to 20 m to complement the current TDR information. In-situ measurements of material properties may also be undertaken.

Reports available

A-Cubed Inc. 1984. Radar surveys at the EMR/INAC monitoring sites along the Norman Wells pipeline route, December 1983. Report to Energy, Mines and Resources, Canada. 50pp.

A-Cubed Inc. 1984. Digitization, processing and display of Mackenzie Valley pipeline radar data collected December 1983. Report to Energy, Mines and Resources, Canada. 41pp.

A-Cubed Inc. 1985. Radar surveys at the EMR/INAC monitoring sites along the Norman Wells pipeline route, June 1984. Report to Energy, Mines and Resources, Canada. 56pp.

A-Cubed Inc. 1985. Electrical property measurements of the 1984 Norman Wells pipeline core samples. Report to Energy, Mines and Resources, Canada. 119pp.

A-Cubed Inc. 1985. Radar and TDR measurements carried out along the Norman Wells, NWT to Zama, Alberta pipeline route in September 1984. Report to Energy, Mines and Resources, Canada.

A-Cubed Inc. 1985. Radar and TDR measurements carried out along the Norman Wells, NWT to Zama, Alberta pipeline, May 1985. Report to Energy, Mines and Resources, Canada. 2 volumes.

Burgess, M.M. 1986. Norman Wells Pipeline Monitoring Sites - Ground Temperature Data File: 1984-1985. Earth Physics Branch Open File 86-6. Earth Physics Branch, Energy, Mines, and Resources, Canada. 21pp. plus appendices.

Burgess, M., J. Pilon & K. MacInnes 1986. Permafrost Thermal Monitoring Program Norman Wells to Zama Oil Pipeline. Proceedings Northern Hydrocarbon Development Environmental Problem Solving Conference, Banff, Alberta, Sept. 24-25, 1985. pp. 248-257.

Granberg, H.B. 1985. Equipment installation report for permafrost climate project at Schefferville and Norman Wells. Report to Atmospheric Environment Service, Environment Canada. 39pp. (unpublished).

Hardy Associates (1978) Ltd. 1984. 1984 EMR instrumentation program, Norman Wells to Zama pipeline. Report to Energy, Mines and Resources, Canada. 161pp.

Hardy Associates (1978) Ltd. 1985. 1985 EMR instrumentation program, Norman Wells to Zama pipeline. Report to Energy, Mines and Resources, Canada. 205pp.

Pilon, J.A. and M.M. Burgess 1984. Thermal impact on permafrost of the Norman Wells to Zama pipeline construction and operation - Progress Report October 1984. Division of Gravity, Geothermics and Geodynamics, Earth Physics Branch, Energy, Mines and Resources, Canada. 7pp.

Pilon, J.A., A.P. Annan, and J.L. Davis. 1985. Monitoring permafrost soil conditions near a buried oil pipeline using ground probing radar and time domain reflectometry techniques. Extended abstract. 55th Annual International Meeting of the Society of Exploration Geophysicists, Washington, D.C., Oct. 6-10, 1985.

Upcoming Reports in 1987

1. Norman Wells to Zama Pipeline, Permafrost and Terrain Research and Monitoring Programme: Site Establishment Report

2. Norman Wells to Zama Pipeline, Permafrost and Terrain Research and Monitoring Programme: Progress Report 1983-1986.

3. Norman Wells Pipeline Monitoring Sites - Ground Temperature Data File: 1986.

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Table 6.1 Site Descriptions

EMR-INAC Site Number	Site	Pipeline km Post	Description (at time of establishment)
84-1	Pump Stn. 1	0.1	Ice-rich silty clay material in widespread permafrost
84-2	Canyon Creek		
	A	19.0	Level location, frozen till with low ice content in widespread permafrost
	B	19.3	East-facing ice rich slope in widespread permafrost, 1m insulating woodchip cover
	C	19.6	Westfacing ice-rich slope in widespread permafrost with an erosion control berm
84-3	Great Bear River		(Joint IPL site)
	A	79.2	Stratigraphically complex ice-rich alluvial terrace deposits in widespread permafrost; cliff-base
	B	79.4	Cliff top lacustrine deposits with veneer of aeolian deposits
85-7	Table Mountain		(Joint IPL site)
	A	270.8	Ice rich lacustrine plain (old seismic line)
	B	271.5	Helipad clearing at bend on top of north facing slope, ice-rich lacustrine plain
	C	271.8	New clearing on level ice-rich lacustrine plain
84-4	Trail River		(Pipeline previously traversed frozen ground)
	A	477.3	Unfrozen saturated sands and silts in dune hollow
	B	477.4	Dry sand and silts in dune crest
85-8	Manner's Creek		(Rapidly changing permafrost conditions)
	A	556.9	Thin peat with thick (10 m) permafrost
	B	557.2	Thick (2.7 m) peat with thin (4 m) permafrost
	C	557.4	Thin peat (1 m) with thin (4 m) permafrost
85-9	Pump Stn. 3	582.5	Frost free granular soils after long frozen section
85-10	Mackenzie Hwy South		
	A	587.5	Transition from a helipad clearing in unfrozen terrain to
	B	587.9	Thin (3 m) permafrost with 2 m peat cover
85-11	Moraine S.	596.6	Thin (4 m) permafrost in helipad clearing
85-12	Jean Marie Creek		
	A	607.7	Thin unfrozen peat plateau
	B	607.9	Thick ice-rich peat plateau; 4 m permafrost
85-13	Redknife Hills		
	A	681.2	Frozen (6 m) terrain surrounding large fen
	B	681.4	Frozen (6 m) terrain at fen border
	C	681.6	Unfrozen terrain in fen
84-5	Petitot R. North		
	A	781.9	Ice-rich peat (3.5 m); (15-18 m) permafrost
	B	782.2	Very thick icy peat (7 m); total 12 m permafrost
84-6	Petitot R. South		
		818.0	Thick (5 m) ice-rich peat; 7 m permafrost

Table 6.2 Schedule of permafrost and terrain research and monitoring field work from November 1985 through November 1986.

Date	Observer	Purpose
1985		
November 13, 15	L. Schmidt, N. Sancartier	Northern data (INAC)
November 20	J.Hayes, W. Lafleur	Southern data (INAC)
December 12, 13, 16	K. Beraska, B. Hoover J. Hayes, D. Trudeau, W. Lafleur	Southern data (INAC)
1986		
January 14, 17	P. Rivard, N. Sancartier L. Schmidt	Northern data (INAC)
January 13 - 15	B. Hoover, W. Lafleur K. Beraska, D. Trudeau	Southern data (INAC)
February 21	D. Elliott	Northern data (INAC)
February 19 - 20	J. Hayes, W. Lafleur	Southern data (INAC)
March 3 - 5	K. MacInnes, J. Pilon W. Pollard	Northern data (INAC, EMR) (Km. 0 - 273, 528)
March 12, 24, 26	D. Trudeau, W. Lafleur K. Beraska	Southern data (INAC)
April 9 - 10, 12	D. Trudeau, B. Hoover W. Lafleur	Southern data (INAC)
April 29	B. Hoover (with IPL)	Southern pipe thermistors (INAC)
April 30	L. Schmidt, N. Sancartier	Northern data (INAC)
May 23 - 28	M. Burgess. W. Pollard	Data - all sites (EMR)
June 19 - 23	D. Harry, K. MacInnes	Data - all sites (INAC EMR)
June 27 - 28	A. Judge, J. Pilon	Radar survey Gt. Bear (EMR)
July 14 - 19	K. MacInnes	Data - all sites (INAC)
August 1 - 11	K. MacInnes, C Tarnocai	Data - all sites (INAC)
	D. Kroetsch	Install soil probes (Ag. Canada)
September 18 - 25	H. Baker, L. Goodrich	Canyon Ck. equipment (NRC)
September 25 - 30	K. MacInnes, F. Adlem, H. Baker	Data - all sites (INAC NRC)
October 23 - 29	M. Burgess, V. Allen	Data - all sites (EMR)
November 12	D. Elliott, L. Schmidt, P. Rivard	Northern data (INAC)
November 19 - 20	P. Trudeau, B. Hoover	Southern data (INAC) Km. 270 - 607

Observers include staff from Indian and Northern Affairs Canada (INAC) Region and District (NWT), Energy, Mines and Resources (EMR, Ottawa) Agriculture Canada (Ag.) and National Research Council (NRC). Northern data refers to sites from Km. 477 - 607 unless indicated. All sites refer to sites from Km. 0 - 818.

Table 6.3 Site Descriptions for the Norman Wells pipeline soil temperature study

Site No.	Site	Pipeline km Post	No. of Probes	Terrain type	Description of material	Method of monitoring
1	Pump Station 1	0.05	2	mclp	ice-rich silty clay	manual
2	Canyon Creek (2A)	19.0	2	mclv / Mg	frozen till	recorder
3	Great Bear River (3A)	79.2	3	msAt	ice-rich alluvial terrace	recorder
4	Table Mountain (7A)	270.8	2	mclp-S	ice-rich lacustrine silt	recorder
5	Table Mountain (7B)	271.8	2	mclp	lacustrine silt	recorder
6	Trail River (4B)	477.4	2	sEd	well drained dune sand	manual
7	Marner's Creek (8A)	556.9	2	pOf-T	0.6 m peat underlain by unfrozen silt	manual
8	Marner's Creek (8B)	557.2	2	pOf-T	2.7 m frozen peat underlain by unfrozen silt	manual
9	Marner's Creek (8C)	557.4	2	pOf-T	peat (fen) thin permafrost	manual
10	Mackenzie Hwy. (10A)	587.5	2	fMg (pOv) / Mg	till	manual
11	Jean Marie Creek (12B)	607.9	2	pOb	frozen peat (peat plateau)	manual
12	Redknife Hills (13C)	681.6	2	pOb (pOb) / Mg	unfrozen peat (fen)	manual
13	Petitot River N.	782.2	2	pOb	7 m thick ice-rich peat	manual

Figure 6.1 Monitoring sites locations

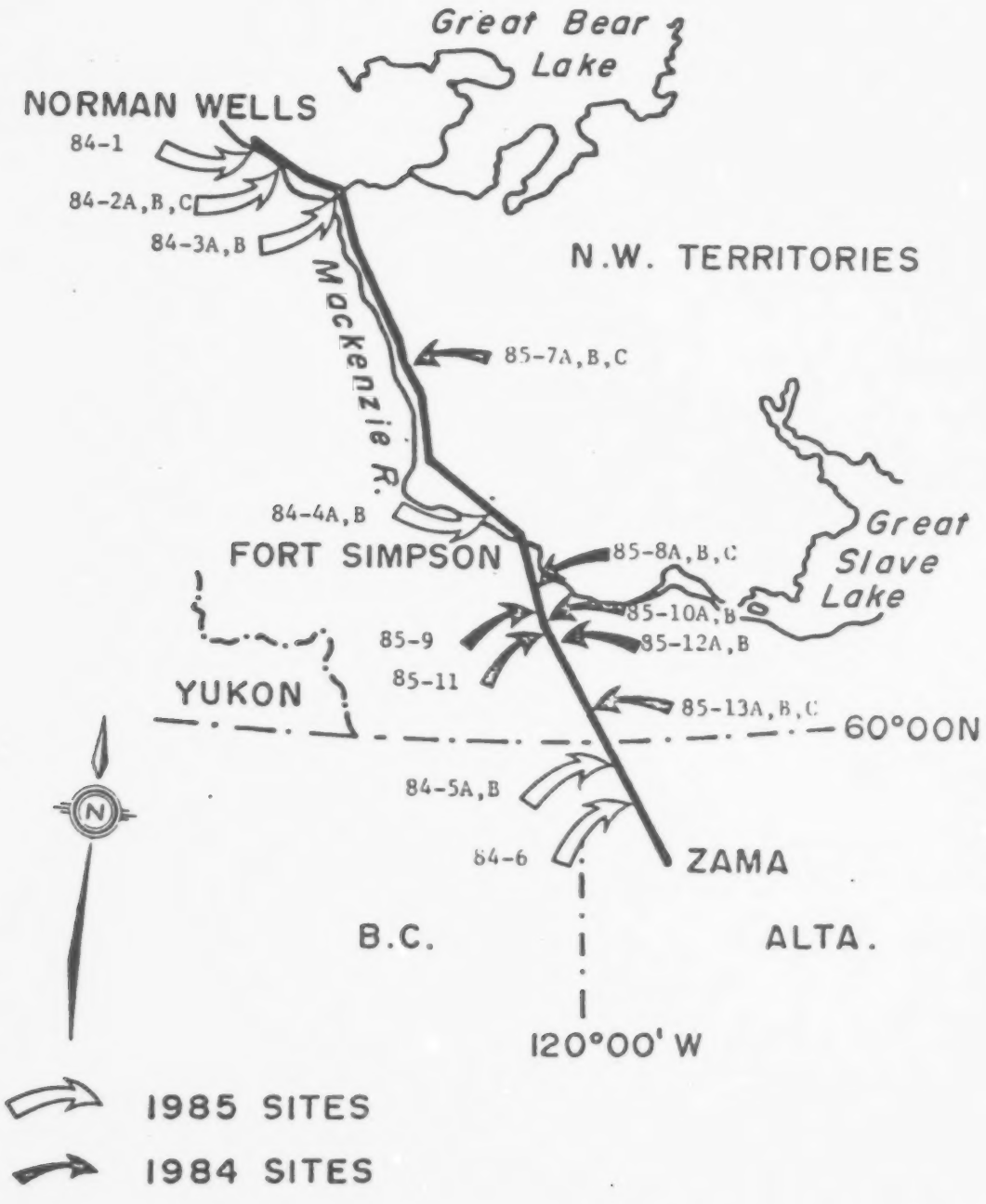


Figure 6.2 Ground temperature envelopes at the Norman Wells pump station Sept. 84 - Sept. 85

The short cables plotted in the top figure illustrate a thermal disturbance resulting from trenching. Cable T1 is located at the edge of the trench which has subsided and filled with water. As a result of the water accumulation, much warmer conditions were observed in the active layer.

The bottom figure illustrates the effect of snow removal during winter construction. A larger-than-normal heat loss resulted over the ROW, since an effective insulating layer was lost. This is reflected in the colder minimum temperatures at depth recorded at T3 and the larger envelope amplitude than at T4.

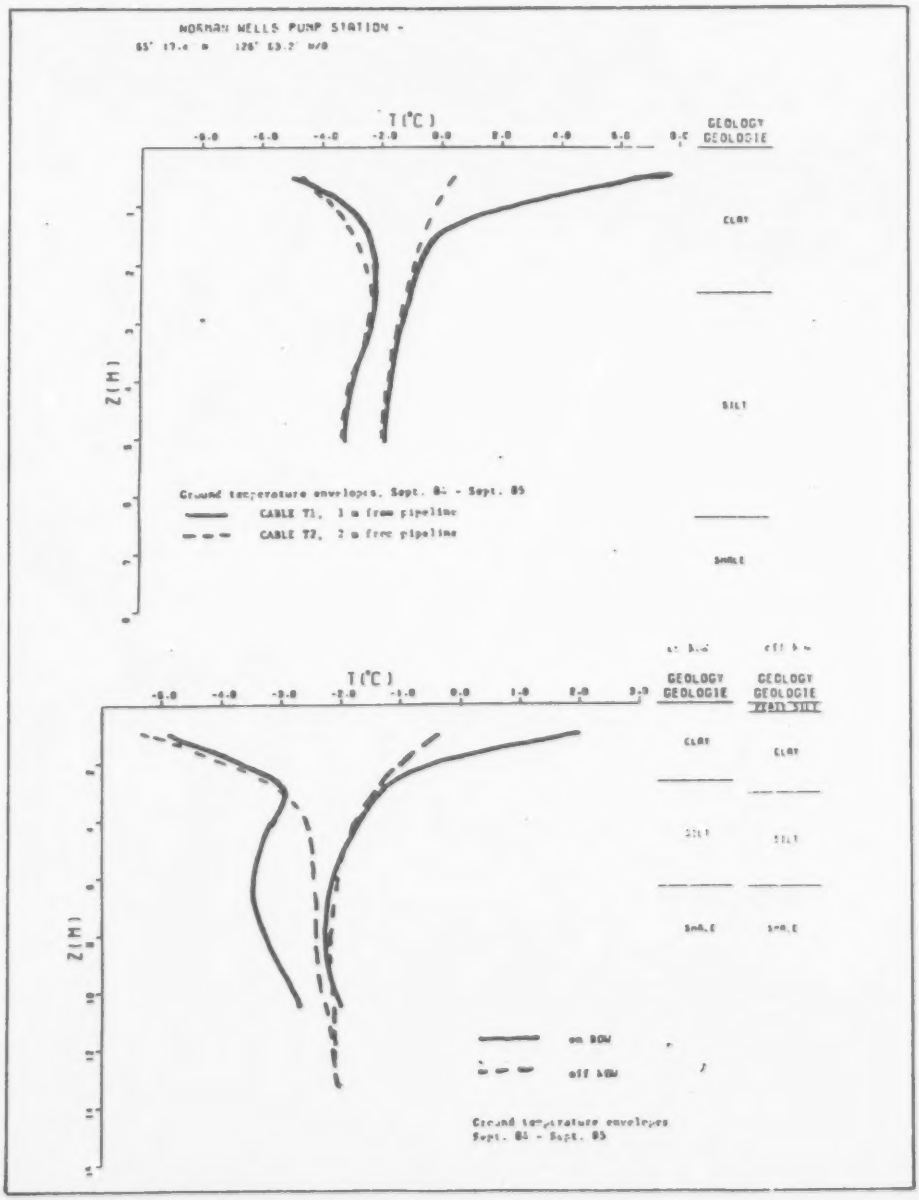


Figure 6.3
Ground temperature envelopes at Canyon Creek B Sept. 84 - Sept. 85

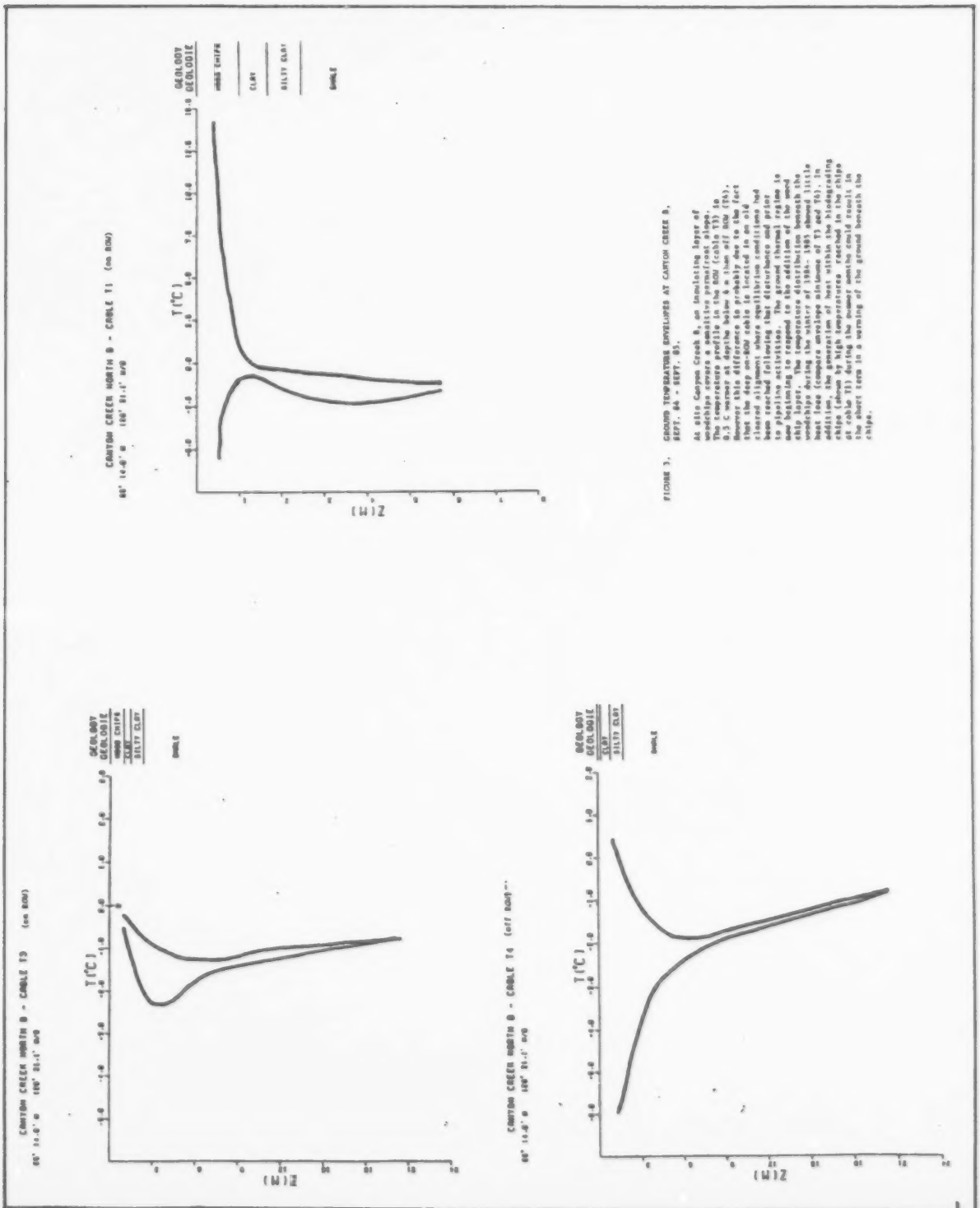


Figure 6.4 Ground temperature envelopes, March 85 - Sept. 85
Mackenzie Highway south T2 cables, A and B sites are 400 m apart.

At this location, there is a transition from unfrozen terrain to very thin permafrost terrain (A to B), and from thin to thick peat (A to B). These short cables illustrate the markedly different thermal envelopes.

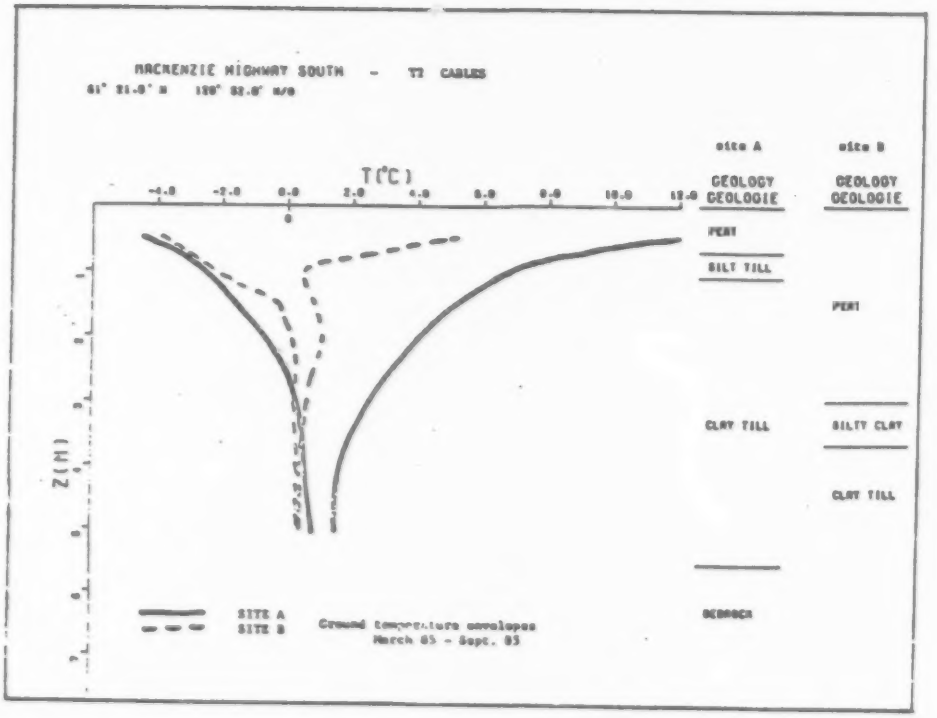


Figure 6.5 Ground temperature envelope, March 85 - Sept. 85, Mackenzie Highway south A, cable T3 on ROW.

The removal of snow during site construction created a deep frozen layer which persisted throughout the summer. This is shown by the very small amplitude at a depth of 2 m (the temperatures were all below 0^{o} C).

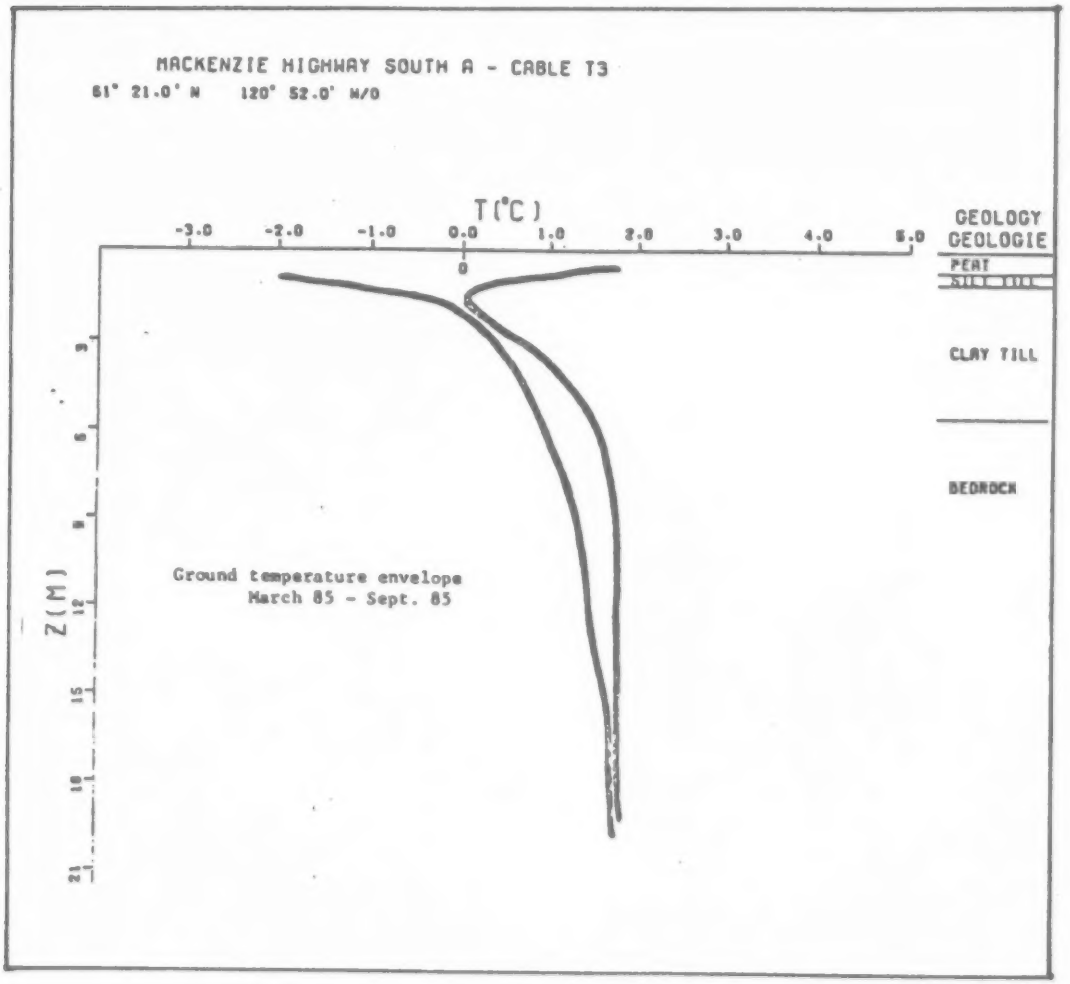


Figure 6.6 Ground probing radar (GPR) profile obtained at site 84-3B in May 1985. Note the continuous profile of the active layer variation obtained with this type of measurement.

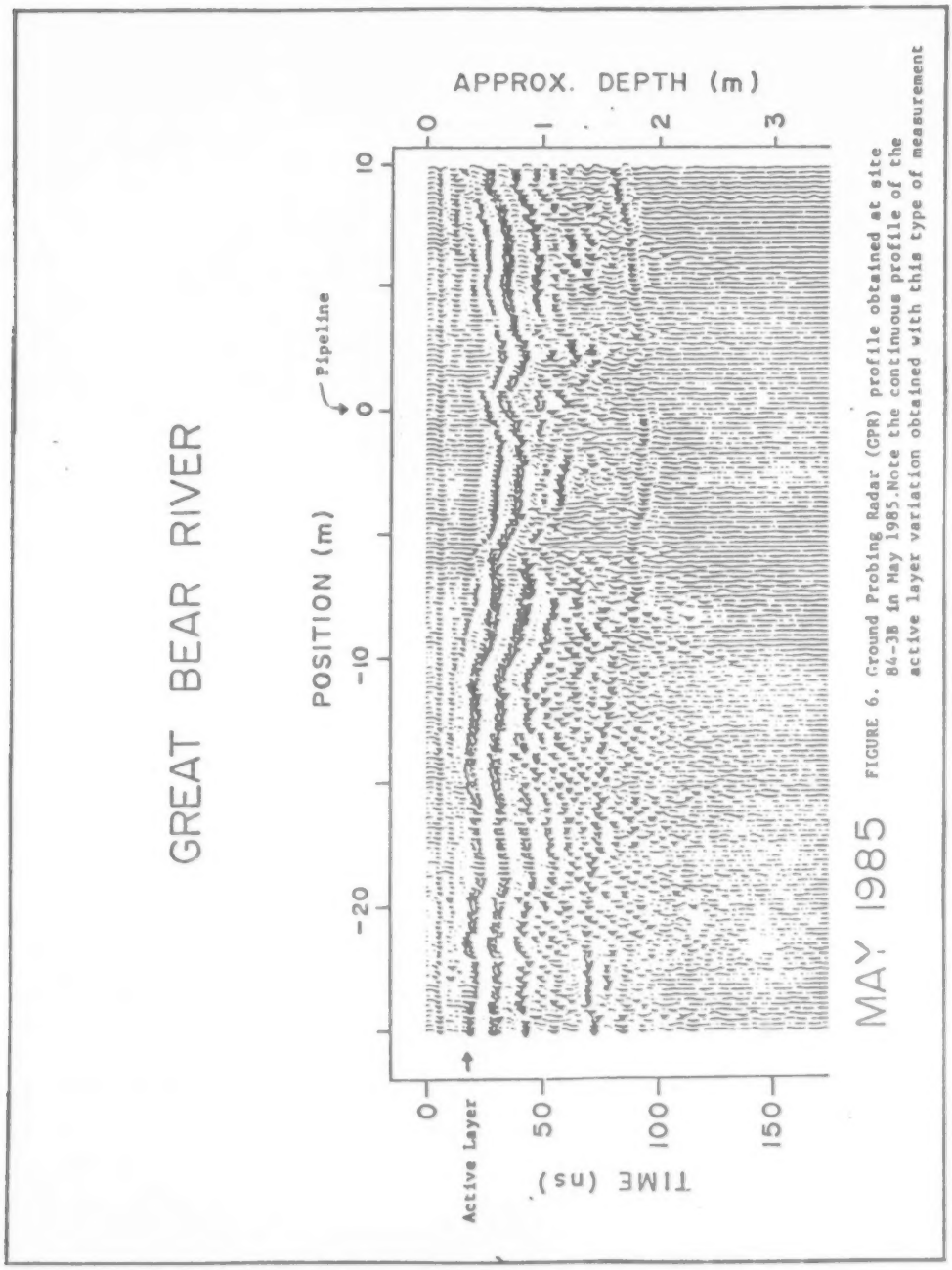
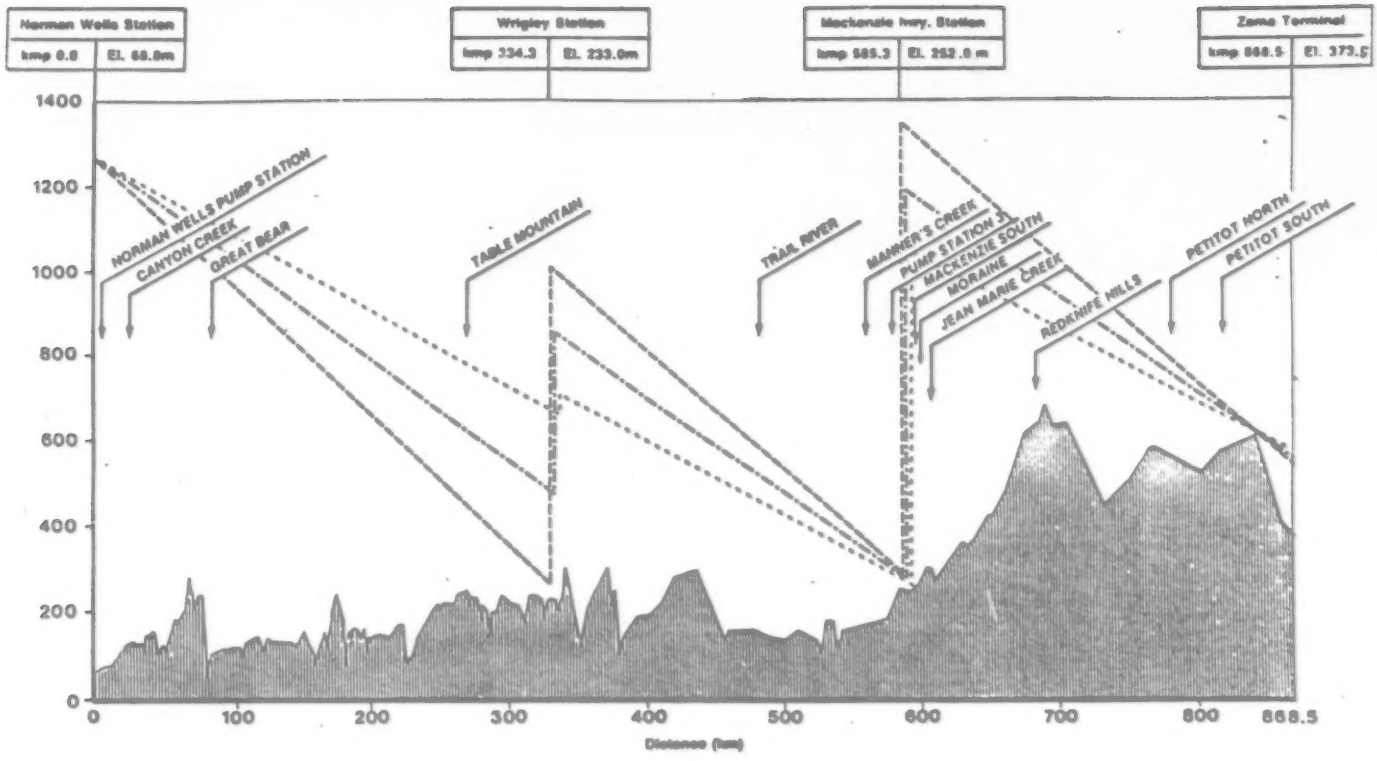


Figure 6.7 EMR/INAC monitoring sites



7. STUDIES OF ENVIRONMENTAL EFFECTS OF DISTURBANCES IN THE SUBARCTIC (SEEDS)

Agency Responsible

Department of Geography, University of Alberta

Funding Agency

Canadian Forestry Service, Northern Forest Research Centre
Department of Agriculture

Start-Up Date

May 1984.

Objectives

In an appropriate subarctic forest stand:

1. conduct a detailed monitoring of controlled experimental studies designed to manipulate disturbances that are themselves a simulation of a transport corridor in a subarctic forest ecosystem,

2. test, under controlled field conditions, several rehabilitation/ revegetation treatments to determine their relative merits, and,

3. develop a preliminary computer model that simulates the site conditions (Subarctic Environment Response Model - SERM) and test it with the data collected over the duration of the project.

Location

The research site is located north of Fort Norman and east of Bear Rock (Figure 7.1).

Results to Date

The study site is an homogeneous terrain/vegetation unit with ice-rich fine-grained soil on a gentle slope. The vegetation cover consists of a decadent (>200 yrs.) black spruce stand with feathermoss/Cladonia lichen ground cover.

A 690 m-long simulated right-of-way (25 m wide) has been hand cleared. A 553 m-long trench of 2 m width was excavated and half of its length was first infilled with insulating organic material prior to backfilling.

The biotic and abiotic environmental characteristics are being described in detail on undisturbed (control), trenched, and cleared areas. An ecosystem approach is being taken and a number of separate studies have been designed to assess the various components (Table 7.1).

At the SEEDS site, a 25 m wide corridor was created over a 2 year period (Figure 7.2). The north-south oriented corridors were identified as ROW 1, 2, and 3 from west to east. In ROW 1, a complete trench was created, including the east-west link. ROWs 1 and 3 were completed in 1985 and ROW 2 was installed in 1986 with its trench. Within the trench, alternating 50 m stretches were backfilled with slash prior to the soil backfilling operation (Table 7.2). The slash was intended to act as a biodegradable insulative material. Trenching was done to the base of the active layer, an average of 50.7 cm (n=129, SD=14.6) and the organic surface layer, including the moss and lichen layer, was mixed back with the mineral soil.

A number of surface test treatments were installed. They included combinations of seeding with agronomic or native species mixes or shrub whip plantings, and insulating or not insulating (Table 7.2).

Seven of these species were agronomics that were also used in the nearby Norman Wells Project while the remainder were locally collected ecotypes. (Table 7.2).

Ecosystem Description

1. Abiotic

Microclimate

A network of automated dataloggers was established within the study area. It consisted of control, cleared right-of-way, and trenched areas with six, one, and nine sites with soil/permafrost and atmosphere parameters being sensed (Table 7.3). Soil/permafrost climate sensors were employed to log temperature data to a maximum of 225 cm with as many as six sensors positioned at various depths. There were a number of sensor depths that were common to all sites (0, 10, 50, and 200 cm below the moss surface).

Soil/substrate

Predisturbance soil sampling was conducted at 5 m intervals along the simulated pipeline trench (Figure 7.2). These studies were initiated in 1985 with the collection of over 380 samples from 49 soil pits (Evans and Kershaw, 1986). A further 300 samples were removed in 1986 and all these collections are currently undergoing laboratory analyses for moisture content, organic matter content, texture, and macronutrient content. A set of soil temperature sensors were installed in 1984 (Table 7.3) and data on temperature profiles are currently being collected on a 12 month basis by automated dataloggers.

Permafrost

Permafrost studies rely on four sources of data:

a. Seventy cores extending 1.5 to 2.25 m below the moss surface were sunk to install thermocouple strings, frost tubes, and bedstead benchmark posts (Figure 7.2). Material removed during this network installation will be analyzed in the lab to provide quantification of ice contents and texture with a resolution of from 5 to 15 cm layers (coring depths between sample removal) (Kershaw and Evans, 1986);
b. Microclimate instruments and associated thermocouple network data are collected continuously from disturbed, reclamation test treatments and undisturbed sites from depths down to 2 m below the permafrost table (Table 7.3);
c. Frost tubes have been inserted in certain core holes (Figure 7.2). Approximately 30 will eventually be installed and monitored;
d. Weekly thaw depth surveys are conducted along transects that extend through the cleared rights-of-way from undisturbed forest (Figure 7.2). This will be extended to include a larger portion of the study area.

Topography

Topographic surveys have been initiated to quantify the subsidence occurring as a result of thermokarst processes. Intermediate-scale surface topography was surveyed throughout the cleared rights-of-way and mesoscale topographic maps will be produced to spatially define the situation at the time of clearing. This will serve to illustrate drainage systems during spring runoff and to define the scale of subsidence associated with the simulated pipeline trench.

As resolution provided by mesoscale mapping is inadequate to record

microscale relief changes, a number of bedstead measurement sites were installed to quantify these topographic changes. This will enable measurement of extent and magnitude of heave, subsidence, and rill erosion.

Over the next few years, any surface elevation changes resulting from either thermal erosion or thermal subsidence will be quantified. A resolution of 1 mm is anticipated for these microscale measurements.

Hydrology

Surface runoff is restricted to the snowmelt period and the rare event of torrential rainfall. During the thaw season, a system of gauges will be installed to monitor discharges. Tracer dye may be used to determine residency time and source of runoff.

Subsurface flow within the active layer will be monitored during the thaw season to provide data to evaluate the extent of soil heat flux associated with soil water.

2. Biotic

Litter Fall

Litter traps were installed flush with the moss surface within the undisturbed area and ROW 3. A fine nylon mesh filter lined the traps to collect organic matter. Trays were emptied on a monthly basis during the snowfree period and the contents weighed and separated into components based upon species.

Litter decomposition

Nylon packets containing litter were deployed within undisturbed and disturbed areas to determine the rate of decomposition for 11

different types of litter. Included were leaf material only from the dominant evergreen shrub - labrador tea (Ledum groenlandicum); 3 deciduous shrubs - bearberry and 2 willows (Arctostaphylos rubra, Salix arbusculoides, and S. myrtillifolia); evergreen tree - black spruce (Picea mariana); a grass (Arctagrostis latifolia); and a sedge (Carex membranacea). Sixty-five sites were selected in each of the control area and ROW 1 (i.e. 130 sites in total) (Table 7.3). In addition, 100 filter paper packets were also deployed.

Vegetation:

A base set of quadrats was selected randomly in the control area and ROW 1 (Figure 7.3). These sites were roughly surveyed and permanently marked for resurvey. Approximately half of the 60 quadrats were phenology plots and the other half were biomass plots harvested in 1985 or 1986. Floristics and cover within each of these plots was described.

Floristics:

Quadrats randomly selected for phenology and biomass studies on the site were inventoried for species composition. A voucher collection of all species of vascular and nonvascular plants was made and a flora list was compiled for each quadrat.

Plant Cover:

A visual estimate of cover was made for each plant species in the sample quadrats. All vascular and nonvascular plant species were included in this analysis.

Plant Phenology:

Plant phenotypic states were monitored throughout the growing season within 38 ROW 1 and 30 control quadrats (Figure 7.3). Fourteen and twenty surveys were completed in 1985 and 1986 respectively. Vegetative and reproductive phenophases were categorized and the first occurrence of each was noted. The quadrats are permanent and therefore year to year variations in phenotypic states can be compared for each species on a quadrat as well as a study basis.

Plant Vigour:

Two evergreen shrubs - labrador tea and crowberry (Ledum groenlandicum and Empetrum nigrum); 4 deciduous shrubs - 2 willows, bearberry, and blueberry (Salix myrtillifolia, S. arbusculoides, Arctostaphylos rubra, and Vaccinium uliginosum); 2 sedges (Carex membranacea and C. vaginata); and a grass (Arctagrostis latifolia) were selected for analysis of vigor. These 11 species form the dominant understory cover and biomass of the vascular plants. Each specimen was divided into component parts and these were measured to determine dimensions (leaf width, length of underground shoots, etc.) (Figure 7.3).

Resprouting

To determine the nature and amount of resprouting from the root mass following a clearing operation, 150 Salix arbusculoides were randomly selected and denuded to ground level prior to clear cutting ROW 2. S. arbusculoides was the dominant erect shrub and the only species present in large enough numbers to be sampled in this fashion. All above ground portions were separated into the same categories as the erect shrubs in the vigor studies. At the end of each growing season, beginning in 1986, 30 of these permanently marked specimens

will be removed and root crowns excavated to determine minimum age estimates.

Phytomass

Within the undisturbed area and the cleared right-of-way, all vascular plant matter (above ground living tissue) below 150 cm height was cleared from selected plots (Figure 7.3). All material was then divided according to species into living and dead components; tree discs were removed for age determinations and cones counted according to the year of their formation.

Propagules:

Both on-site and off-site sources of propagules are important to revegetation of disturbed terrain. Core samples of on-site propagules were removed, maintained in a moistened condition in a greenhouse, and monitored for sprouting. Off-site propagules were analyzed by transects and litter-fall traps. Three snow sampling transects are surveyed three times annually. All seeds are filtered out of the meltwater produced from the snow cores.

Herbivory:

Insects:

A pilot study was initiated to determine the suitability of pitfall traps in assessing insect populations and species diversity. Traps were checked every 14 days and collections retained to verify field identifications.

Mammals

Fourteen small mammal traplines containing 10 traps each were installed across ROW 3 (Figure 7.4) prior to its clearing and

monitored during and immediately following the clearing operations. These lines were run during two periods in 1985 and three periods in 1986. In 1986, the traplines were doubled in length and number of traps to include ROW 2. All animals were weighed and marked for recapturing. Distribution and composition data were collected and, in conjunction with these studies, exclosures to prevent foraging activities were installed to determine the impact of small mammal use of vegetation in the trench area. A set of exclosures will be removed each year and biomass clipping conducted to determine differences between excluded and open foraging areas.

Conclusions and Recommendations

Based upon a partial analysis of data collected over the first two years of the study, the following conclusions can be drawn:

1. The year to year variations in abiotic and biotic ecosystem components can be substantial.

2. Two years of data are insufficient to accurately describe changes in ecosystem components. It appears that a minimum of five years data will be necessary to provide a reliable, short-term, quantitative description of ecosystem processes in the subarctic.

3. Internal characteristics of such "fixed" ecosystem components as soils and permafrost are extremely variable and require large sample sizes at a high density to form reliable characterizations.

Future Studies

A number of study components will be modified in the 1987 field season. These will include a surface runoff and active layer

through-flow study with the possibility of some dilution gauging experiments to determine the nature and source of water movement on the site. Improvements will be made to the existing microclimate network with greater emphasis being placed upon the radiation budget. Ecophysiological studies will be conducted to gain a better understanding of the plant functions that are affected by surface disturbances. The fate of fertilizers applied to the soil surface will be under study with extensive foliar analysis and soil nutrient work.

Certain studies that were initiated in 1985 may be curtailed and efforts focussed on new work.

Reports Available

Beckingham, J. 1986. The effects of human induced linear disturbances on vascular plant phenology in a decadent black spruce Subarctic forest. Unpubl. BSc. thesis, Department of Geography, University of Alberta. 86pp.

Kershaw G. Peter, and K.E. Evans. 1986. Soil and near-surface permafrost characteristics in a decadent black spruce stand near Fort Norman, N.W.T. B.C. Geographical Series No. 44:151-166.

Kershaw, G. Peter, and Matt Fairbarns 1985. Studies of Environmental Effects of Disturbances in the Subarctic (S.E.E.D.S.). Year End Report 1984-85. Department of Geography, University of Alberta, Edmonton.

Kershaw, G.P. manuscript. Ecosystematic analyses in the development of reclamation guidelines for Subarctic environments. The Boreal Institute for Northern Studies 25th Anniversary Volume.

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Table 7.1 Components of the Studies of the Environmental Effects of Disturbances in the Subarctic (SEEDS) project, Fort Norman, N.W.T.

Ecosystem Components	Principal Investigators 1984-1986 (alphabetical order)
ABIOTIC	
Permafrost characteristics	
Active layer	K. Evans, B. Gallinger, I. Shukster
Near-surface permafrost	K. Evans, B. Gallinger, I. Shukster
Microclimate characteristics	
Atmosphere/boundary layer	T. deGrosbois, P. Kershaw
Soil/permafrost	K. Evans, B. Gallinger, P. Kershaw L. Maslen, K. Evans
Surface Hydrology	
Runoff characteristics	B. Gallinger
Soil characteristics	
Physical	K. Evans
Nutrient	K. Evans
Litter	
Litterfall	L. Kershaw, P. Kershaw L. Maslen, K. Evans
Decomposition	L. Kershaw, P. Kershaw L. Maslen, K. Evans
BIOTIC	
Vegetation	
Floristics	L. Kershaw
Community description	L. Kershaw
Phenology	J. Beckingham, I. Shukster
Productivity	L. Kershaw, P. Kershaw, D. Schotte
Phytomass	L. Kershaw, P. Kershaw, D. Schotte
Vigour/Plant physiology	T. deGrosbois, L. Kershaw, P. Kershaw
Herbivores	
Small mammals	A. Legris, L. Maslen
DISTURBED ECOSYSTEM COMPONENTS	
ABIOTIC	
same as above	
BIOTIC	
same as above	
Propagules	M. Fairbarns, P. Kershaw, L. Maslen
Revegetation	
Agronomics/fertilizer	K. Evans, P. Kershaw
Native species - seeds	L. Maslen
- shrub whips	L. Maslen
- resprouting	L. Maslen, B. Gallinger

Table 7.2 Plant species involved in test reclamation treatments on a simulated pipeline trench, SEEDS, 1985-86.

Species	Test Treatment Number										
	1I	2I	3	4	5I	6I	7I	8	9I	10	11
AGRONOMIC SEED											
Poa pratensis	x		x								
Festica ovina	x		x								
F. rubra	x		x								
Agropyron pauciflorum	x		x								
Alopecurus arundinaceus	x		x								
Phalaris arundinacea	x		x								
Phleum pratense	x		x								
NATIVE SEED											
Arctagrostis latifolia					x						x
Carex membranacea					x						x
Epilobium angustifolium					x						
Empetrum nigrum						x					
Betula glandulosa						x					
Arctostaphylos rubra						x					
Ledum groenlandicum						x					
NATIVE SHRUB WHIPS											
Betula glandulosa							xS	xS	xC	xC	xS
Alnus crispa							xS	xS	xC	xC	xS
Vaccinium uliginosum							xS	xS	xC	xC	xS
Potentilla fruticosa							xS	xS	xC	xC	xS
Salix arbusculoides							xS	xS	xC	xC	xS
S. glauca							xS	xS	xC	xC	xS

I: insulated with biodegradable material
C: control collections
S: seismic line collections

Table 7.3 Key ecosystem components measured in the Subarctic *Picea mariana* stand that was the focus of SEEDS

Components	Control	Right-of-way	Trench Reclamation Treatments 1I	2I	3	4	5I	6I	7I	8	9I	10	11
			(number of replicates)										
ABIOTIC													
Atmospheric microclimate													
sensible heat													
+150 cm	2	1					2						
+ 50 cm	1	1					2						
+ 10 cm	2	1					2						
0 cm	6	1											
relative humidity													
+150 cm	1	1					2						
+ 50 cm							1						
+ 10 cm	1	1					2						
net radiation													
+150 cm	1						1						
global radiation													
+150 cm	1	1											
wind speed													
+300 cm	1	1					1						
+150 cm	1	1					1						
precipitation													
rain	1	1											
snow		1											
evapo-transpiration	2	6			1	1							
Soil/Substrate (Active Layer)													
temperature													
- 2.5 cm	1	1	1	1	1	1	1						
- 5 cm													
-10 cm	1	1	1	1	1	1	1						
-25 cm		1			1	1							
moisture content)													
texture)	50 soil pits and 63+ cores sampled												
organic matter)													
nutrients)													
Permafrost													
temperature													
- 50 cm	1	1	1	1	1	1	1						
- 75 cm			1	1	1	1	1						
-100 cm				1			1						
-150 cm	1	1			1								
-200 cm	1	1	1	1	1	1	1						
-225 cm				1									
thaw depth progression (weekly)	123	156	15	15	15	15							
ice content	14	49	2	2	2	2							
texture	14	49	2	2	2	2							
Hydrology													
runoff	1	1				1							
through-flow	1	1				1							
Topography													
mesotopography) topographic map encompassing the entire site microtopography	3	3			7	8							

I: insulated with biodegradable materials

Table 7.3 continued — Key ecosystem components measured in the Subarctic *Picea mariana* stand that was the focus of SEEDS

Components	Control	Right-of-way	Trench Reclamation Treatments 1I	2I	3	4	5I	6I	7I	8	9I	10	11
			(number of replicates)										
			BIOTIC										
Litter fall													
litter decomposition	13	13											
Vegetation													
floristics	60	68	Not applicable										
cover	60	68	Not applicable										
phenology	30	38	Not applicable										
vigor	30	30	Not applicable										
phytomass	24/13	24/13	Not applicable										
productivity	24/13	24/13	Not applicable										
propagules	24	30	6										
Natural Revegetation													
floristics	NA	NA	To be conducted in 1987										
cover	NA	NA	To be conducted in 1987										
phenology	NA	NA	To be conducted in 1987										
vigour	NA	NA	To be conducted in 1987										
phytomass	NA	NA	To be conducted in 1987										
productivity	NA	NA	To be conducted in 1987										
propagules	24	30	To be conducted in 1987										
shrub resprouting	NA	30	To be conducted in 1987										
Assisted Revegetation													
floristics	NA	NA											
cover	NA	NA	60	60	60	60							
phenology	NA	NA											
vigour	NA	NA											
phytomass	NA	NA	NA	60	NA	60							
productivity	NA	NA											
seed viability)		for species used in seeding trials											
shrub whip planting	NA	NA											
Herbivory - Small Mammals													
abundance distribution		2520 trap nights covering 3 periods during snow-free season on entire site											

I: insulated with biodegradable materials
NA: not applicable

Figure 7.1 Location of the simulated disturbance installed for the project - Studies of the Environmental Effects of Disturbances in the Subarctic (SEEDS), Fort Norman N.W.T.

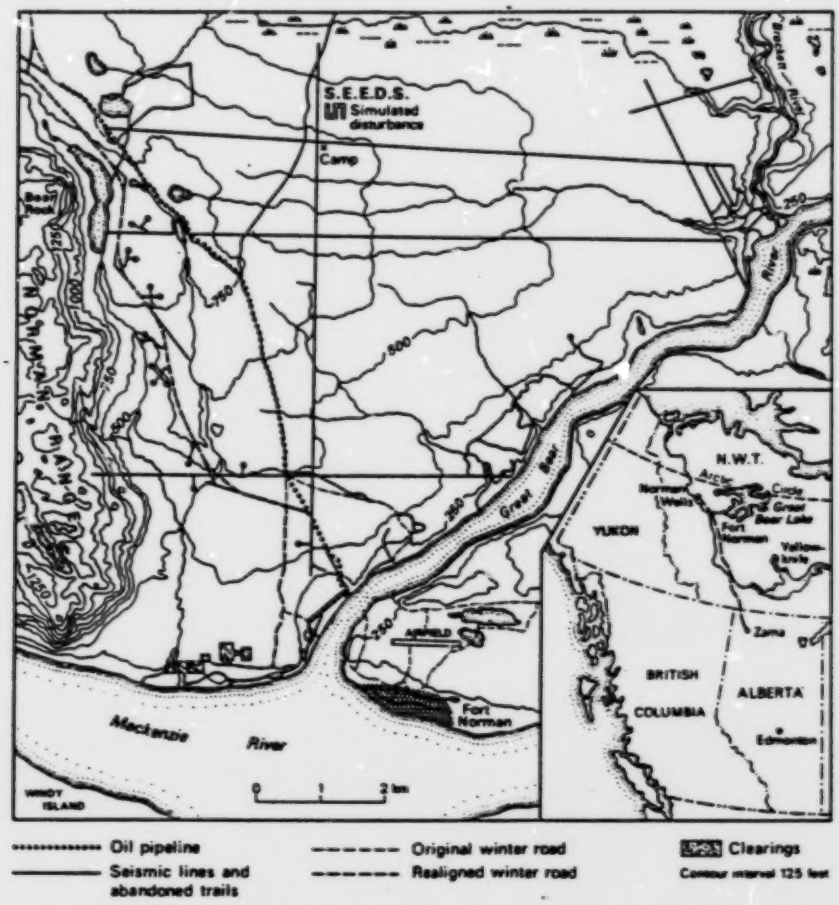


Figure 1 Location of the simulated disturbance installed for the project – Studies of the Environmental Effects of Disturbances in the Subarctic (SEEDS), Fort Norman, N.W.T.

Figure 7.2 Abiotic baseline and monitoring networks.

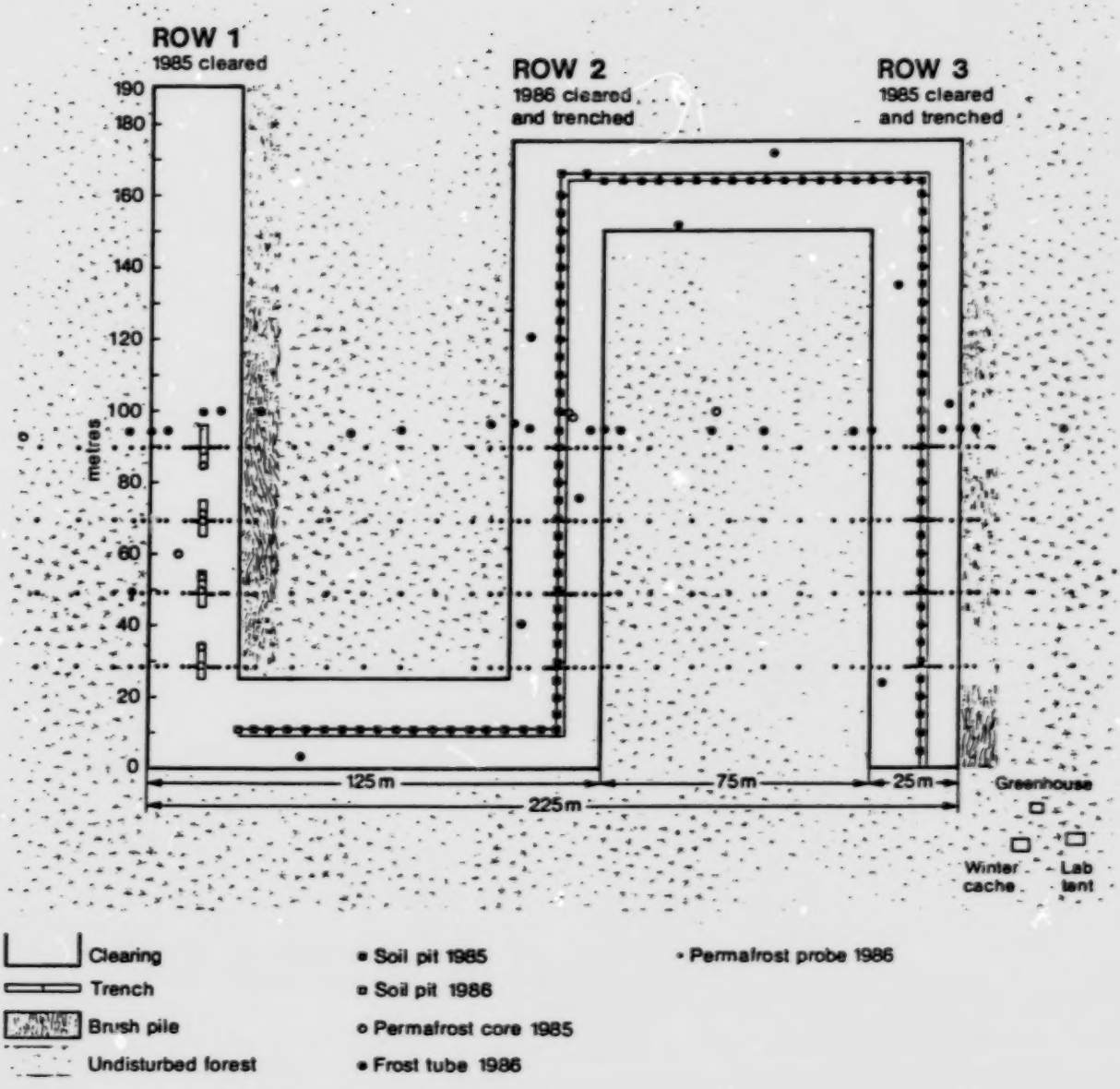


Figure 7.3 Biotic baseline and monitoring networks

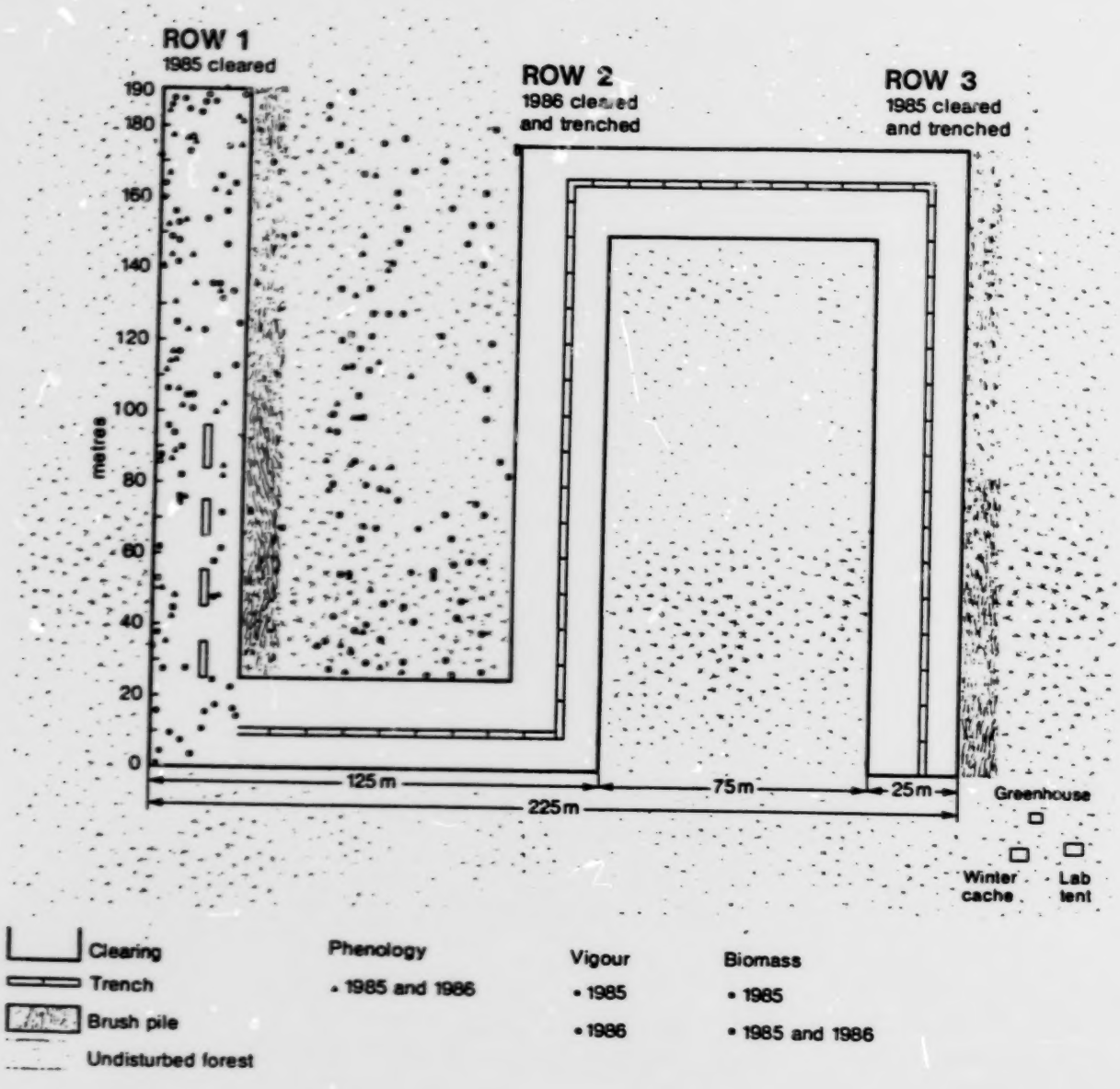
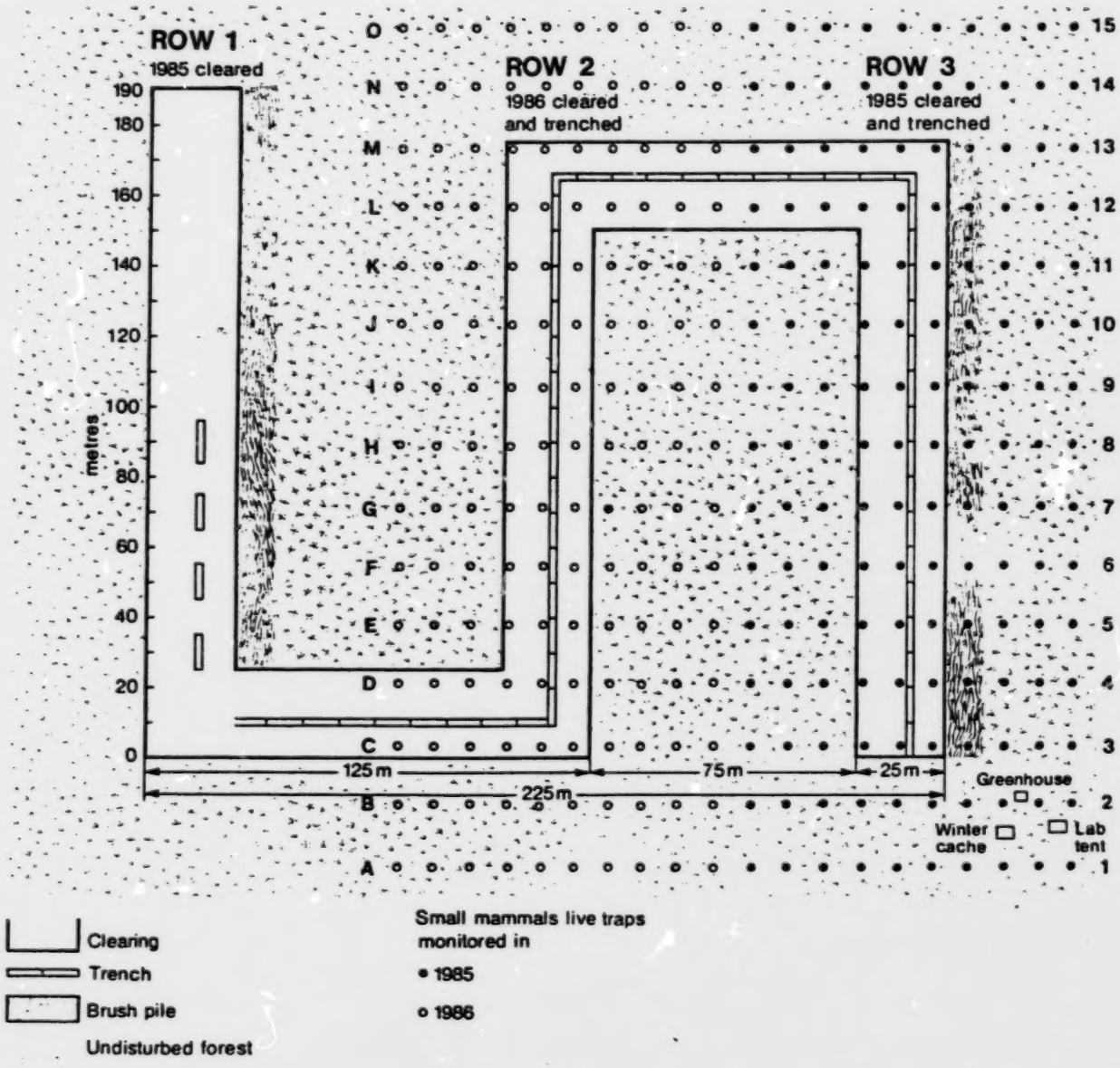


Figure 7.4 Approximate location of small mammal live trapping network



8. MACKENZIE RIVER CONTAMINANTS PATHWAYS

Agency Responsible

Environmental Protection, Department of the Environment

Start-up Date

February, 1985

Objectives

Main Objectives:

1. to develop effective criteria for protecting aquatic resources from the impacts of contaminants from petroleum developments, and

2. to produce recommendations on the most effective methods for monitoring impacts on the Mackenzie River of contaminants released from petroleum developments.

Sub-Objectives:

1. to identify the environmental pathways of petroleum hydrocarbons and metals from such sources as the Norman Wells refinery and natural oil seeps, and

2. to determine the impacts of petroleum hydrocarbons and metals from anthropogenic sources at Norman Wells on fish and other aquatic biota (eg. toxicity, bioaccumulation and consumer acceptability).

Part I: February - April 1985

1. chemical characterization of crude oil, cooling water, and refinery effluent from the Norman Wells Oilfield Development

in order to identify the potential toxicity of constituent contaminants,

2. review of the literature and of ongoing research on the effects of contaminants from similar developments, and the environmental pathways of these contaminants, and

3. preparation of a design for a research program to examine the effects of hydrocarbons and other contaminants from the Norman Wells Oilfield Development.

Part II: April 1985 - April 1986

1. chemical characterization of natural oil seeping into the Mackenzie River in the vicinity of Norman Wells at a level of detail to allow for chemical differentiation between the seepage hydrocarbons and those originating from the Norman Wells development,

2. assessment of lethal and sublethal effects of the refinery effluent and the natural oil seepages through in situ (or a combination of laboratory and in situ) exposure of fish from the Mackenzie River. The sublethal effects evaluated include behavioural effects, tainting, bioaccumulation of petroleum hydrocarbons, and biochemical/enzymatic indicators of exposure to hydrocarbons,

3. chemical characterization of water, bottom sediment, and suspended sediment in association with the fish exposure tests, and

4. comparison of the potential impacts of hydrocarbons from the seeps and from the effluent on fish exposed under ice cover and under open water conditions.

Part III: April 1986 - April 1987

1. assessment of the effects of petroleum hydrocarbons from natural seepages and from the Norman Wells Oilfield Development on the quality of water in the Mackenzie River. The study area includes the Mackenzie River from Norman Wells to Fort Good Hope,

2. assessment of the relationship between the condition of livers of burbot and Arctic grayling from the study area, the concentrations of metabolites of selected polynuclear aromatic hydrocarbons (PAH's) in bile, and selected hydrocarbons in muscle and liver tissue from populations of these fish species, and

3. assessment of the acceptability of samples of burbot liver for consumption by knowledgeable residents of the study area, using reproducible methods.

Locations

1985: immediate vicinity of Norman Wells
1986: from Norman Wells to Fort Good Hope

Results to Date

Parts I & II (1985)

Chemical Characterization of Hydrocarbon Sources

Detailed results of analysis of the crude oil, refinery effluent, refinery cooling water, and a natural oil seepage by gas chromatography and mass spectrometry are presented in the referenced report. In general, the results were:

1. The refinery effluent and cooling water contained fewer hydrocarbon compounds than the crude oil, particularly the more volatile aliphatics and aromatics.

2. The refinery effluent and cooling water contained basically the same compounds, with relatively lower concentrations in the cooling water.

3. Analysis of parameters such as oil and grease, phenols, and sulphides in the refinery effluent indicated lower concentrations relative to other Canadian refineries.

4. Fresh natural seep oil, collected as it emerged from the river sediment off Bosworth Creek, was found to closely resemble the crude oil in chemical composition.

Toxicity of Refinery Effluent and Seep Oil

1. Field Tests

To assess the effect of disposal of refinery effluent on Mackenzie River fish, burbot and Arctic grayling were caged in the river immediately downstream of the refinery outfall and at seep areas upstream and downstream of the outfall (Figure 6.1). Control locations were also included. The fish were held in these locations for 10 days.

Neither the refinery effluent nor the seep oil caused significant (ie. 50% or greater) mortalities over the 10 day exposure period. The death of two to five grayling at the upstream control site was attributed to the increased stress of the faster current there.

Following the removal of the caged fish from the river, single burbot

from each site were flown to Fort Good Hope where the acceptability of the livers was judged by local people. The remaining five livers from each site were judged by the contract biologists based on their observations of the community evaluation (Tables 8.1a and 8.1b).

Since the community evaluation was based on assessment of only one burbot liver from each site, it provides only a general indication of the variability of individual responses. The results of evaluation of all six livers from each site shows a general relationship between exposure of burbot to the seep and refinery sources of hydrocarbons.

2. Lab. Tests

a. Acute Toxicity

Burbot from the Mackenzie River and rainbow trout were exposed to undiluted refinery effluent and various concentrations of the crude oil in the laboratory (insufficient seep oil was available). Grayling could not be transferred to the Vancouver lab because of potential parasitism. The 96hr LC50 of the crude oil was 3,000 ppm. The refinery effluent was not acutely toxic.

b. Chronic Toxicity

Rainbow trout were exposed for 10 days to undiluted refinery effluent and to concentrations of 1,000 ppm, 18 ppm, and 5 ppm of the crude oil water-soluble fraction in covered and uncovered tanks to simulate open water and ice cover conditions. Burbot were exposed to 1,000 ppm and 5 ppm crude oil under open conditions only.

The refinery effluent was toxic to rainbow trout in the closed vessels (9 out of 10 fish died). No mortalities occurred in the open test tanks. All the trout exposed to 1,000 ppm oil died, but no

mortalities occurred in 189 ppm or 5 ppm oil. Therefore, a threshold concentration could not be calculated for the water soluble fraction of the crude oil for the 10 day test.

Two of three burbot in 1,000 ppm crude oil died, indicating that the threshold concentration was somewhere below 1,000 ppm.

3. Chemical Analyses

a. Water and Sediment

Results of chemical analysis of samples of water, suspended sediment, and bottom sediment taken at the fish cage locations in the Mackenzie River are shown in Table 8.2.

Total aliphatic hydrocarbon concentrations in water (based on a C-20 standard) were below the detection limit of 10 ug/l at all locations except the upstream oil seep (station 5), where 56.5 ug/l were measured. Total aromatic hydrocarbons were all below the detection limits for individual compounds of 5-20 ug/l. Suspended sediment samples taken at the upstream and downstream sites produced detectable concentrations of aliphatics (9.8 ug/g and 16.0 ug/g, respectively).

Unsieved bottom sediment samples from the six sites produced detectable levels of aliphatics ranging from 3.7 ug/g to 148 ug/g. Although the highest level was found at station 5, results from the other sites did not show a pattern consistent with the locations of the hydrocarbon sources.

b. Fish Bile, Liver and Muscle

Field Exposures

Analysis of two polyaromatic hydrocarbons (PAH's), benzo(a)pyrene and phenanthrene, in burbot and Arctic grayling bile from the cages showed a consistent pattern among the locations (Table 8.2 and Figures 8.2.a and 8.2.b.) Relative concentrations of benzo(a)pyrene and phenanthrene were significantly greater in grayling at sites 3 and 5 (the refinery effluent and oil seep areas, respectively) than in control fish. Grayling collected on the opposite side of the river from Norman Wells had twice the maximum phenanthrene and benzo(a)pyrene levels measured in the caged fish, likely as a result of more prolonged exposure to hydrocarbon sources.

Analysis of volatile aromatics in burbot liver showed decreased concentrations of the three most abundant compounds (ethyl benzene, m,p-xylene, and o-xylene) in those fish exposed to the refinery effluent and seep oil. However, grayling muscle concentrations of these compounds were increased through exposure to the refinery effluent, but not the seep oil. Grayling from the opposite side of the river had the highest concentrations of aromatics in muscle samples.

Lab. Exposures

Concentrations of benzo(a)pyrene in burbot bile were increased by exposure to undiluted refinery effluent and to 5 ppm and 1,000 ppm crude oil (Table 8.3). Burbot accumulated comparable levels of the PAH's from refinery effluent as from the 1,000 ppm solution of crude oil (about 85 units), but exposure to 5 ppm crude oil produced lower bile concentrations (41 units). A lower uptake of benzo(a)pyrene by rainbow trout occurred with exposure

to refinery effluent than to either concentration of crude oil. No difference was found in uptake between the two concentrations of crude; however, significantly less uptake of PAH from crude oil occurred in trout tested in covered tanks than in open tanks. There was no difference in trout bile PAH levels in fish from open and closed tanks after exposures to refinery effluent.

Rainbow trout accumulated greater concentrations of three volatile aromatic hydrocarbons in muscle under covered exposure to 1,000 ppm crude oil and refinery effluent, as compared to exposure under open conditions. Burbot liver aromatics were not measured in lab.-exposed fish.

Part III (1986)

Field collections of water and fish took place in late September; however, preliminary results were not available until early December. The final report is due in spring, 1987.

Conclusions and Recommendations

Parts I & II (1985)

1. Field exposures of burbot and Arctic grayling to natural oil seeps and refinery effluent demonstrated the increased uptake of PAH's in bile and increased concentrations of three volatile aromatics in muscle tissue of grayling exposed to the refinery effluent but not to the seep oil. Neither hydrocarbon source was toxic to the two species in 10 day tests. Further studies were recommended to examine the relationship between bile and muscle uptake of aromatic hydrocarbons and the histopathology of fish liver.

2. Aliphatic and aromatic hydrocarbon levels in water were below

detection limits at all but one location, a seep area. Bottom sediment analyses were poorly correlated with the hydrocarbon sources and did not indicate downstream accumulation of hydrocarbons, likely due to the lack of a depositional environment in the study area.

Further sampling of water and suspended sediment at improved detection limits was recommended in order to delineate sources of petroleum hydrocarbons.

3. The undiluted refinery effluent was not acutely toxic to burbot or rainbow trout,but was toxic to rainbow trout held in covered tanks for 10 days. The crude oil was found to be toxic to both species at 1,000 ppm, but not at 5 ppm in both open and closed tanks.

4. The lab exposures produced increased uptake of PAH's in bile, similar to the field tests. However, there were indications of differences between the uptake of aromatic hydrocarbons by burbot and rainbow trout which could not be conclusively demonstrated because of the small numbers of fish analyzed.

Future Studies

The recommendations from the 1985 study were implemented in the 1986 study. Due to the absence of a confirmed control population of Mackenzie River burbot with healthy livers, it was decided to examine the relationship between bile and muscle PAH levels and induction of mixed function oxidases, and gross and detailed histopathology of burbot and grayling livers. Measurement of concentrations of aliphatic and aromatic hydrocarbons in Mackenzie River water and in suspended sediment between Norman Wells and Fort Good Hope was also included in the 1986 study. Since quantification of aqueous

hydrocarbon concentrations in relation to uptake by fish was required, methods were evaluated to increase the detectability of hydrocarbons in water.

A decision on requirements for the 1987 phase of the study is dependent on the 1986 results.

Reports Available

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Figure 8.1 Sample site locations in the Norman Wells study area

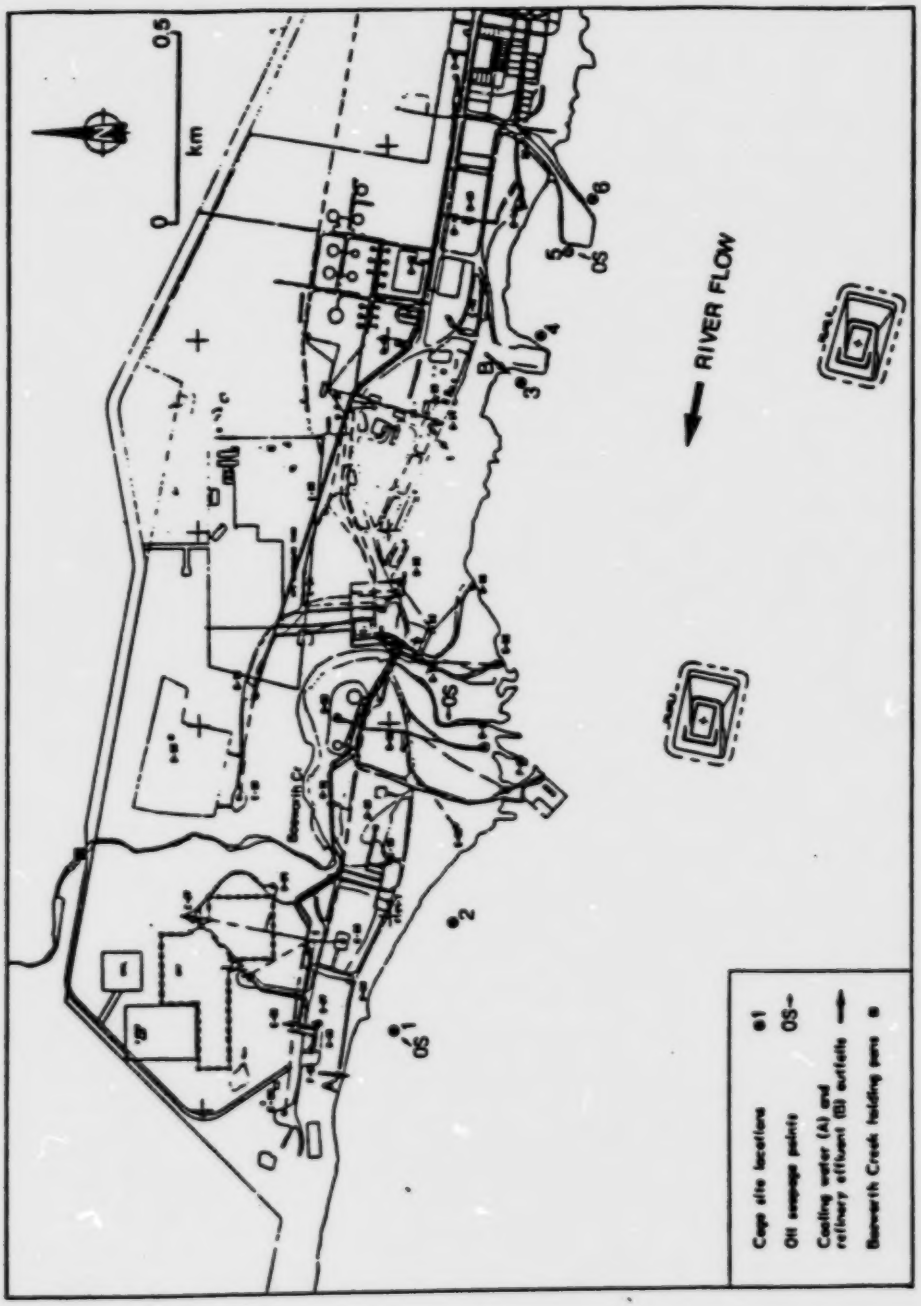


Table 8.1(a) Evaluation of burbot livers displayed at the Fort Good Hope Community Complex, October 1985

Site Number	Assessment of Livers Number Good	Number Bad	Percentage unacceptable response
1	0	26	100
2	5	21	81
3	5	21	81
4	21	5	19
5	14	12	46
6	25	1	4
7*	25	1	4

*Sucker Creek Control

Table 8.1(b) Evaluation of burbot livers by E.V.S. Consultants

Site Number	Assessment of Livers Number Good	Number Bad	Percentage Bad
1	4	2	33
2	4	2	33
3	3	3	50
4	5	1	17
5	4	2	33
6	6	0	0
7*	6	0	0

*Sucker Creek Control

Table 8.2 Levels of hydrocarbons found in Mackenzie River water, sediments, and exposed fish at Norman Wells compared with liver acceptability test results

Site	Total Aliphatic Hydrocarbons as C-20 Sediment (µg/dry gram)	Suspended Sediments (µg/g)	Surface Water (µg/L)	Burbot Bile Benzo(a)Pyrene (Relative Area) n $\bar{X} \pm$ S.E.	Grayling Bile Benzo(a)Pyrene (Relative Area) n $\bar{X} \pm$ S.E.	Grayling Bile Phenanthrene (Relative Area) n $\bar{X} \pm$ S.E.	Burbot Liver Acceptability (Percentage unacceptable response)	Aromatic Hydrocarbons (Ethyl Benz; m,p-Xyl; o-Xyl) Burbot Liver (ppb) n mean total	Grayling Tissue (ppb) n mean total
Control	-		-	4 6.1 ± 2.6	5 21.2 ± 1.3	3 222.3 ± 37.2	4	2 2,423.1	3 618.8
1	3.7	13.0	L 10	5 14.4 ± 3.8	4 33.4 ± 6.2	2 461.5 ± 267.2	100		
2	18.0		L 10	5 7.1 ± 1.9	4 31.7 ± 8.6	2 510.0 ± 23.1	81		
3	12.0		L 10	3 9.3 ± 3.9	4 51.8 ± 2.3	2 682.5 ± 164.9	81	2 1,288.8	3 965.4
4	5.1		L 10	5 7.7 ± 1.7	4 33.9 ± 9.7	2 482.5 ± 103.8	19		
5	148.0		56.5	5 10.8 ± 3.6	4 52.0 ± 5.6	2 740.5 ± 25.6	46	2 1,405.7	3 514.5
6	5.3	9.8	L 10	5 8.8 ± 5.[illegible]	4 31.1 ± 2.9	2 329.0 ± 96.3	4		
Reference	-		-	-	10 107.1 ± 21.4	2 1,460.0 ± 30.1	-		3 1,116.1

n = number of fish sampled

$\bar{X}$ = mean

S.E. = standard error = standard deviation/$\sqrt{n}$

Figure 8.2(a) PAH uptake by exposed burbot (mean and standard error) compared with liver acceptability test results.

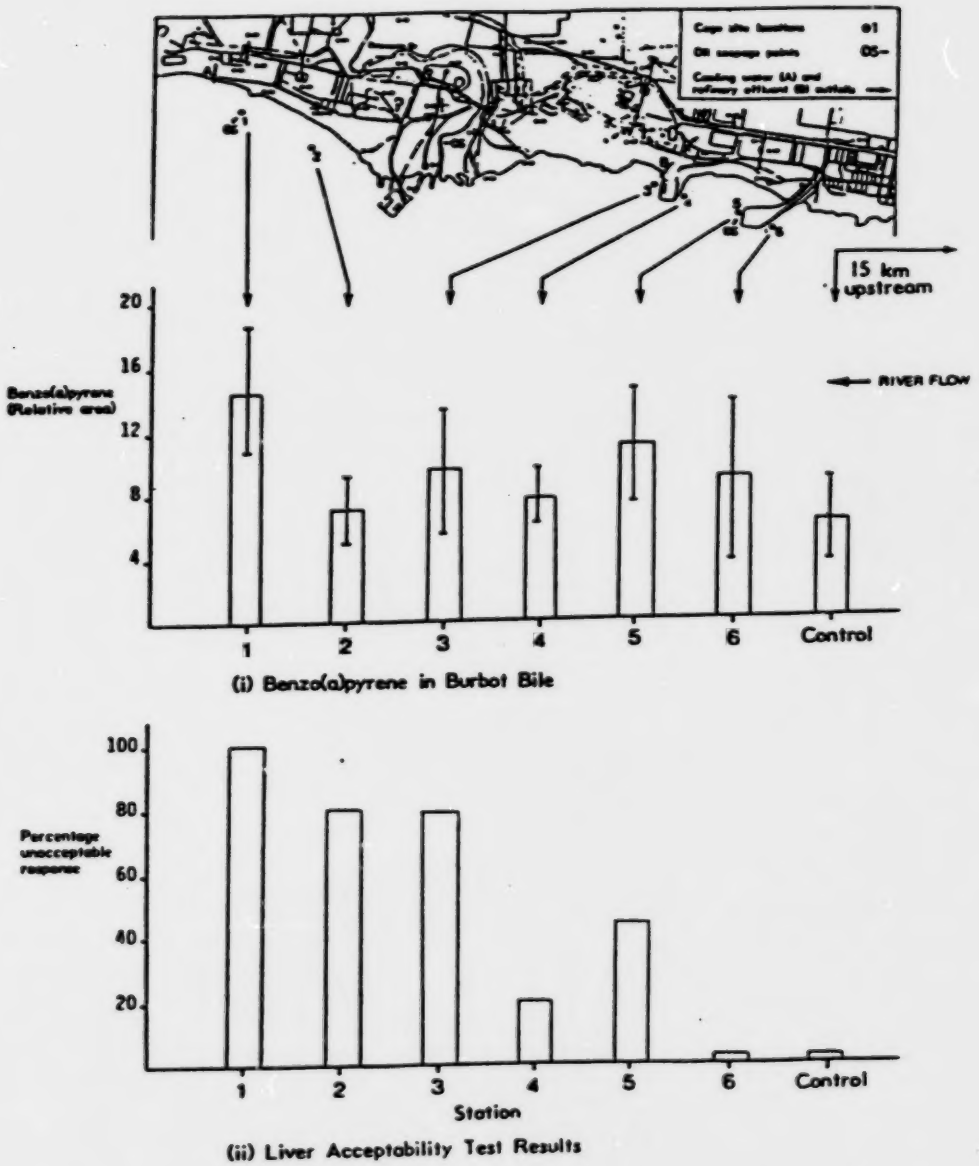
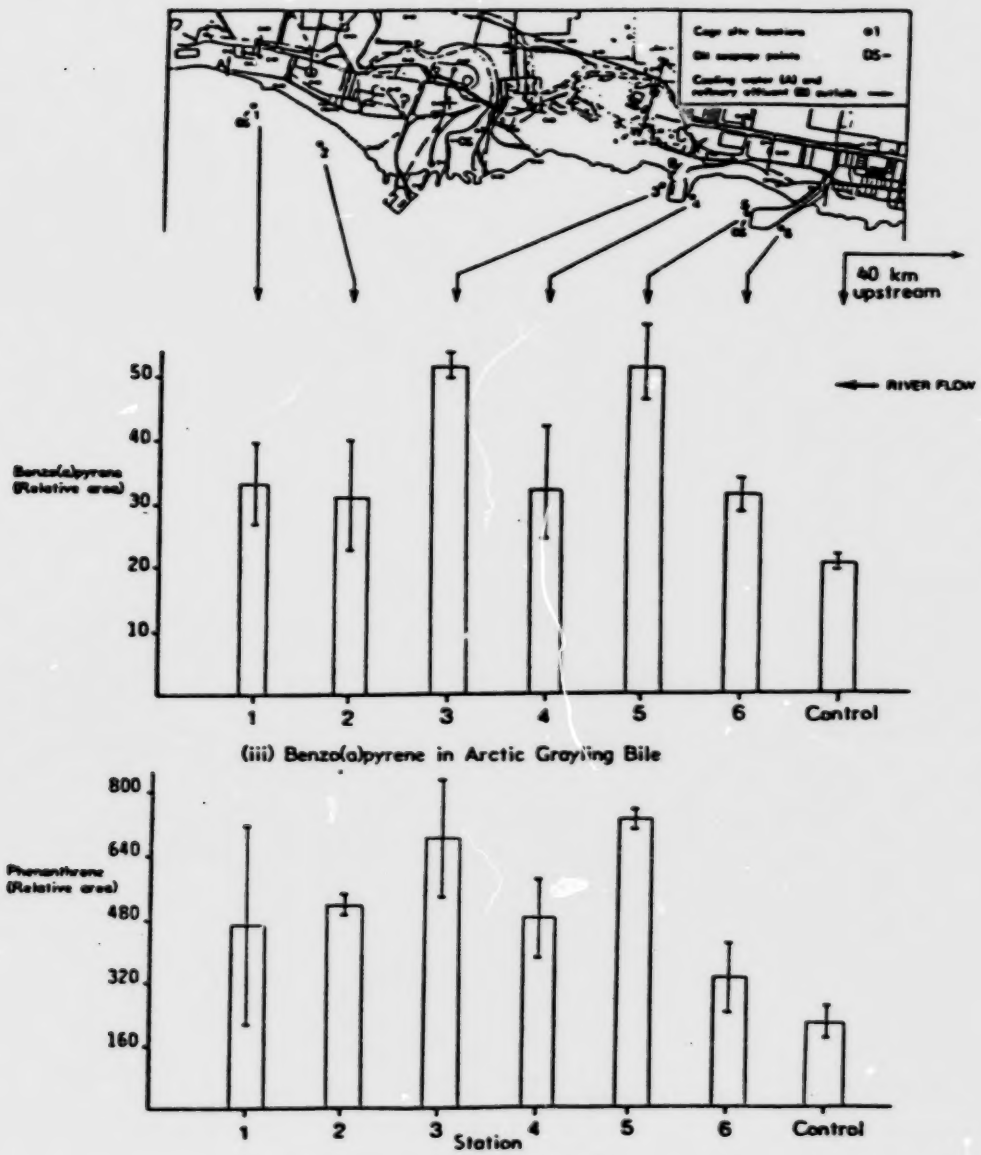


Figure 8.2(b) PAH uptake by exposed Arctic grayling
(mean and standard error)



(iii) Benzo(a)pyrene in Arctic Grayling Bile

(iv) Phenanthrene in Arctic Grayling Bile

Table 8.3 Uptake of benzo(a)pyrene in bile of burbot, Arctic grayling and rainbow trout, and levels of aromatic hydrocarbons in dorsal muscle tissue of rainbow trout.

Sample	Exposure Medium	Exposure Time	Burbot Bile Benzo(a)Pyrene (Relative Area) n	x̄ ± S.E.	Grayling Bile Benzo(a)Pyrene (Relative Area) n	x̄ ± S.E.	Rainbow Trout Bile Benzo(a)Pyrene relative			Rainbow Trout Tissue Aromatic Hydrocarbons (Ethyl Benz; m,p-Xyl; o-Xyl)		
							n[a]	area	condition	n[a]	ppb	condition
Field control	River water upstream from Norman Wells	long term	4	6.1 ± 2.6	5	21.2 ± 1.3		-			-	
Lab control (oil bioassay)	Vancouver dechlorinated water	10 days	3	8.0 ± 2.1		-	1	6.6	open	1	417	open
Lab control (effluent bioassay)	Vancouver dechlorinated water	10 days	2	6.7 ± 0.4		-	1	6.8	closed	1	586	closed
Field reference	Norman Wells midstream river water	indefinite (fish age ≥ 3 yrs)		-	10	107.1 ± 21.4		-			-	
Site 5 in situ exposure	Norman Wells river water adjacent to oil seep	10 days	5	10.8 ± 3.6	4	52.0 ± 5.6		-			-	
Laboratory oil bioassay (ambient)	5 ppm (v/v) weathered crude oil	10 days	3	41.1 ± 3.8		-	1 1	78.9 15.4	open closed		-	
Laboratory oil bioassay (threshold)	>50 ppm (v/v) weathered crude oil	10 days	3	86.8 ± 37.9		-	1	79.9 N.D.	open closed	1 1	669 1,213	open closed
Site 3 in situ exposure	Norman Wells river water in effluent plume	10 days	3	9.3 ± 3.9	4	51.8 ± 2.3		-			-	
Laboratory effluent bioassay	100 percent refinery effluent	10 days	3	83.9 ± 18.9		-	2 2	33.0 ± 6.9 26.8 ± 5.8	open closed	1 1	712 919	open closed

n = number of fish sampled

n[a] = composite samples from 5 fish

x̄ = mean

S.E. = standard error = standard deviation/√n

- = not determined

9. MACKENZIE RIVER BASELINE MONITORING OF PETROLEUM HYDROCARBONS

Agency Responsible

Water Quality Branch, Inland Waters Directorate (IWD) with the cooperation of National Hydrology Research Institute (NHRI) Saskatoon, and National Water Research Institute (NWRI) Burlington.

Start-up Date

1985

Objectives

1. to develop methods for monitoring petroleum hydrocarbons in the water and sediment of the Mackenzie River, and

2. to establish a baseline of petroleum hydrocarbon and metal concentrations in water and sediment upstream and downstream of the Norman Wells oilfield development.

Locations

Eight sample sites were located from Fort Simpson to the Mackenzie Delta (Figure 9.1).

Results to Date

Results from the 1985 low flow survey indicated the presence of hydrocarbons originating from the Liard River system. An aerial reconnaissance survey resulted in the mapping of oil and gas development activities in the basin. Bottom sediment sampling was

subsequently carried out on the NWT portion of the Liard River. Hydrocarbon analysis of these sediments is being completed at the NWRI laboratory.

A second field survey for hydrocarbons and heavy metals was carried out on the Mackenzie River during June 1986 to describe ambient concentrations at high flow periods. Samples of suspended sediment and the water column were taken and are currently being analyzed in NHRI/NWRI laboratories.

The first ambient hydrocarbon baseline data base is now being developed for the Mackenzie River. Preliminary results indicate:

1. Hydrocarbon presence in the Liard River, and
2. Natural seepage as the predominant hydrocarbon source in the Mackenzie River.

Utilization of Results

Prior to the initiation of these NOGAP - sponsored surveys, no effective procedures existed for the monitoring of hydrocarbons in northern aquatic ecosystems. Environmental program managers could not comment on water quality with respect to hydrocarbons. The initial data and knowledge obtained from the first two ambient surveys of the Mackenzie River are rapidly improving this bleak picture. Two critical aspects of hydrocarbon monitoring are now known and used by IWD, as well as other government agencies and consultants, in the design of on-going and future programs:

1. It is now clearly evident that suspended sediments constitute a major pathway for hydrocarbons moving through the aquatic system.

2. Much larger volumes of water (100 litres vs. 1-16 litres) must be sampled in order to identify with precision the presence of

hydrocarbons in northern rivers.

Managers are now able to design monitoring programs which properly and effectively identify the presence and levels of hydrocarbons.

While energy demands fluctuate periodically, it is likely that long-term hydrocarbon development will occur in the Mackenzie basin. These surveys are producing the scientific techniques required to monitor on-going and future hydrocarbon developments. Moreover, they are establishing a data base for ambient levels of hydrocarbons in the Mackenzie River where none previously existed. This data base becomes especially valuable when combined with related NOGAP projects on the Mackenzie River. Based on a scientific monitoring program, it is now becoming possible to comment on the relative importance of Imperial Oil Limited's discharges versus naturally occurring seeps. It is also now evident that the Liard basin constitutes a potentially significant source of hydrocarbons to the Mackenzie system.

Future Studies

An under-ice survey in March 1988 at selected points from Fort Simpson to the Mackenzie Delta will be conducted to detect the presence of light aromatic petroleum hydrocarbons.

Sampling for three additional years through to 1990/91 will attempt to duplicate results to date with respect to suspended sediments, bottom sediments, and water column monitoring during high flow, low flow, and under ice conditions. (Funding for this three year program has yet to be confirmed.)

Reports Available

Environmental Protection Service and Inland Waters Directorate. 1985. NOGAP Project Description for: Criteria for the Control and Monitoring of Petroleum Development Impacts on the Mackenzie River. (includes Environmental Protection component of the study). January 1985.

Nagy, E., J.H. Carey, J.H. Hart, E. Ongley, and J. Tisdale. 1986. Hydrocarbons in Mackenzie River Suspended Sediments. NWRI Contribution No. 86-65. Environment Canada.

Reports in Progress

Hydrocarbons in Mackenzie River Water and Suspended Sediments: 1986 High Flow Survey.

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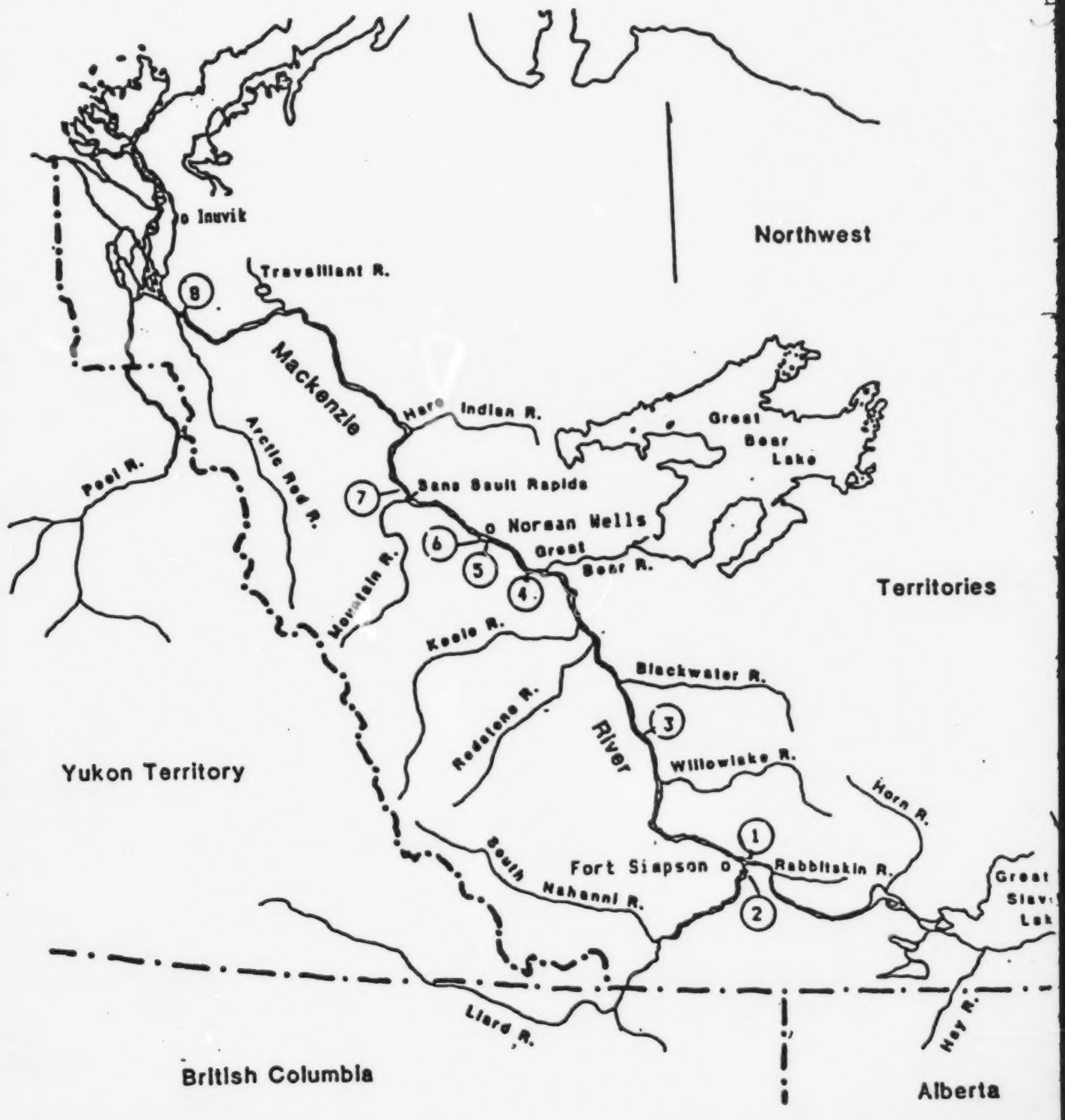
Figure 9.1 Mackenzie River sampling sites 1985



10. FISH QUALITY AND PHYSIOLOGICAL CONDITION

Agencies Participating

Department of Fisheries and Oceans (DFO)
Department of Indian Affairs and Northern Development
Dene Nation

Start-up Date

October 1985

Objectives and Methods

To determine the causes of poor quality fish caught in the lower Mackenzie River by local fishermen, by:

1. collecting fish samples from several Mackenzie River locations to determine the incidence of poor quality fish in the domestic fishery, and

2. analyzing fish and their tissues to determine whether the abnormal conditions occur naturally or result from changes in the environment.

Locations

Arctic Red River, Fort Good Hope, Fort Franklin, and Fort Simpson

Results to Date

The Dene Nation, under contract with DFO, carried out the collection of all fish samples. A minimum of 15 burbot and 15 whitefish were

collected from Arctic Red River, Fort Good Hope, Fort Franklin, and Fort Simpson, with Fort Franklin acting as the control area. All fish were frozen and shipped to the Freshwater Institute in Winnipeg (Table 10.1).

The analyses of samples collected during October, 1985, concentrated on two main areas: possible hydrocarbon exposure and the intensity of parasite infestations.

Conclusions from the preliminary hydrocarbon study data:

1. The complaints about dark colour and small size of burbot liver are legitimate and the condition is prevalent in burbot from several communities (Ft. Good Hope, Ft. Franklin, and Arctic Red River), but the cause(s) of the liver condition is not clear. The condition is partially consistent with at least three potential causes which are not necessarily exclusive of each other, namely:
   a. chronic toxicity of petroleum hydrocarbons
   b. poor nutrition
   c. parasitic infection

   Considering the work of Chen (1969) with liver size measurements of burbot from the Tanana River in Alaska, there is also a strong possibility that the liver phenomenon is natural for river populations of burbot.

   The measurements with the most specific diagnostic capability were the liver mixed function oxidase activities, and these suggested that the fish were not in a state of chronic response to polyaromatic hydrocarbons. If the cause of the condition of burbot liver does include exposure to petroleum hydrocarbons, then clearly Norman Wells is not the exclusive source, or the

burbot from the lake at Ft. Franklin would not have shown the condition. There were no liver tumors found in any of the fish examined.

2. The fish from all locations sampled were contaminated with low levels of low-boiling aromatic hydrocarbons typically present in Norman Wells crude oil and in refined petroleum products. The extent of this contamination indicates a broad environmental source such as deposition from air; however, the level of this contamination at Ft. Good Hope was several times higher in late winter than in late fall, which suggests an additional source of the hydrocarbons under river ice. The winter vs. summer difference was not evident at Ft. Simpson.

3. We have only anecdotal reports on the timing of the appearance of the small, dark livers in burbot. If it has indeed become prevalent only recently, than it is legitimate to search for recent changes in the environment that might offer some explanation. While sample sizes are very small, the limited data do not indicate a decrease in the growth rates of the fish taken in 1985 as compared with those in the early 1970's. Clearly, the liver condition is related to the liver content of fat and calories, and such a relationship suggests the liklihood of a linkage to growth. The absence of a change in growth rate then suggests that the liver condition may have been present, but not reported, for some time.

4. There is widespread contamination of fish from the Mackenzie River with low levels of several organochlorine compounds, notably toxaphene, chlordane, and PCBs.

5. The complaint regarding "watery" flesh of whitefish is also legitimate in that the northern whitefish have higher water

content and lower fat content than most other samples of whitefish for which we have been able to find data.

Conclusions from the parasite study data:

A nematode larva, Raphidascaris acus, increased in intensity with increased liver atrophy in large burbot from the Mackenzie River. A similar increase was also noted for a cestode, Triaenophorus nodulosus plerocercoids, in burbot from Fort Franklin, N.W.T. The correlations that appear to exist between liver atrophy in large burbot and the presence of these pathogenic larvae may be valid. However, it has not yet been determined whether parasite infestations resulted in liver atrophy or if in fact atrophied livers are more susceptible to infestation.

Future Studies

Results from the 1985 samples became available only recently. Therefore, final decisions on future activities have not yet been made. However, it has been recommended that:

1. An experimental starvation study with burbot and whitefish be undertaken to determine whether the observations of small dark liver in burbot and watery flesh in whitefish can be generated by starvation.

2. Sampling of burbot liver be continued periodically for several years in order to discover trends in the levels of organochlorines and hydrocarbons; and that Health and Welfare Canada officials be asked to determine whether consumption of burbot liver might be hazardous in view of the contaminants present.

3. Experimental enzyme induction tests be done with burbot and whitefish to determine the pattern of induction produced by oil, and also by some of the organochlorines found in northern fish (toxaphene, chlordane, PCBs).

4. Experienced older local fishermen be contacted in an effort to determine the historical condition of burbot liver; and that museums be contacted for information on historical collections of burbot with a view to examining preserved specimens for the appearance and size of the livers.

5. Additional communities be contacted for reports to further define the geographic range of burbot liver abnormalities, and to locate a suitable northern"control" site where burbot with acceptable livers can be obtained for enzyme and contaminant analyses.

6. Water and fish from Ft. Good Hope, Norman Wells, and Ft. Simpson be collected late in a winter season for light hydrocarbon analysis to verify the summer vs. winter difference observed at Ft. Good Hope in 1985.

7. Sampling of a range of fish species and sizes be done at several Mackenzie River communities for comparison with growth data from the same areas in the early 1970s.

8. Experimental infection with previously-uninfected captive burbot be attempted to determine whether parasitic infestation results in visible changes in the liver, and further that experiments be devised to test whether sub-lethal stress with hydrocarbons can enhance the severity of parasitic infestation.

9. Systematic survey work on burbot and whitefish biochemistry be started to define the influences of habitat type, season, and

biological variables (sex, age, etc.) on liver condition and body composition.

Reports Available

Bernier, L.M.J. 1986. Liver pathology of burbot Lota lota (Linnaeus) and the parasites Raphidascaris acus (Bloch) and Triaenophorus nodulosus (Pallas) with Notes on Transmission Routes.

Chen, L-C. 1969. The biology and taxonomy of the burbot, Lota lota leptura, in interior Alaska. Biol. Paper Univ. Alaska 11: 53pp.

Lockhart, W.L., D.A. Metner, D.A.J. Murray, B.N. Billeck, C.L. Baron, D.C.G. Muir and K. Chang-Kue. 1986. Studies to determine whether the condition of fish from the Lower Mackenzie River is related to hydrocarbon exposure. A preliminary data report. 121pp.

Contact

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Table 10.1.

Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Sample No.	Fork Length (mm)	Weight (g)	Age (yr)	Maturity	Gonad Weight (g)
Burbot	4	923	4,450	16	female-spent	59
	5	650	1,295	10	female-immature	3
	6	602	1,305	7	female-immature	5
	9	562	1,117	8	male-immature	1
	10	595	1,030	8	male-resting	8
	11	603	1,023	11	male-spent	22
	12	553	728	10	male-resting	5
	13	626	1,380	8	female-immature	5
	14	540	713	8	male-resting	4
	15	754	2,050	14	male-spent	37
	16	775	2,500	14	male-spent	32
	17	702	1,600	11	male-spent	19
	18	645	1,454	7	male-resting	13
	19	600	869	10	male-spent	8
	23	860	3,750	15	female-resting	13
	24	625	1,500	11	female-resting	5
Lake Whitefish	2	383	770	14	female-resting	11
	3	345	554	10	female-resting	5
	8	345	577	10	female-immature	3
	21	398	846	13	male-immature	1
	22	310	346	8	female-immature	2
	25	395	790	16	female-resting	2
	26	346	598	10	male-immature	1
Inconnu	7	860	8,550	15	female-mature	214
	20	440	818	5	male-immature	1
Northern Pike	1	693	2,938	16	male-mature	

Table 10.1. (continued)

Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Liver Weight (g)	Liver % Body Weight	Condition Factor	Consumption Suitability	Histo-[1] pathology	Path-[2] ology
Burbot	79	0.56	.5659	bad	0	-
	27	2.08	.4716	medium	1	-
	165	12.64	.5982	good	2	-
	122	10.92	.6293	good	2	-
	30	2.91	.4890	medium	2	-
	31	3.05	.4666	medium	1	-
	26	3.57	.4305	medium	2	-
	57	4.13	.5625	good	2	-
	17	2.38	.4528	bad	0	1
	40	1.95	.4782	medium	-	-
	128	5.12	.5371	medium	2	-
	60	3.75	.4625	good	1-2	-
	36	2.48	.5419	medium	1-2	-
	23	2.65	.4023	medium	1	-
	321	8.56	.5896	good bad	2	2
	90	6.00	.6144	good	2	-
Lake Whitefish	17	2.21	1.3705	-	3	-
	-	-	1.3491	-	1-3	-
	-	-	1.4051	-	-	-
	-	-	1.3419	-	3	-
	-	-	1.1614	-	3	-
	-	-	1.2818	-	3	-
	-	-	1.4437	-	1-3	-
Inconnu	102	1.19	1.3442	-	3	-
	-	-	.9603	-	3	-
Northern Pike	85	2.89	.8828	-	2	-

[1] Histopathology: 0 - severe atrophy, low lipid content.
1 - mild to moderate atrophy, moderate lipid content.
2 - normal, lipid filled.
3 - actively regenerating/growing.

[2] Pathology: 1 - brown, pea-sized inclusions in liver.
2 - bacterial pathogen Yersinia ruckerii isolated.

Table 10.1. (continued)

Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Sample No.	Trace Metals in Liver (ug/G, wet wt.) Pb	Cu	Cd	Hg	Se	Zn	% moist
Burbot	4	<0.10	22.20	<0.10	0.25	1.02	34.30	79.30
	5	<0.10	25.50	0.28	0.19	2.19	33.10	59.40
	6	<0.10	1.60	<0.10	0.02	0.61	9.79	41.30
	9	<0.10	3.60	<0.10	0.01	1.47	10.80	45.30
	10	<0.10	16.60	0.19	0.04	1.37	30.70	57.10
	11	<0.10	30.10	0.17	0.07	1.94	54.30	69.60
	12	<0.10	23.00	0.25	0.04	1.96	34.80	62.80
	13	<0.10	4.90	0.25	0.05	2.07	15.30	43.30
	14	-	-	-	-	-	-	-
	15	<0.10	34.10	0.35	0.07	2.87	51.60	65.00
	16	<0.10	8.60	0.11	0.03	0.82	20.10	47.90
	17	<0.10	18.00	0.38	0.04	1.69	37.40	58.30
	18	<0.10	27.20	0.28	0.06	1.71	46.70	60.60
	19	<0.10	25.80	0.42	0.04	2.00	43.30	67.20
	23	<0.10	4.30	<0.10	0.03	0.42	12.00	28.90
	24	<0.10	10.00	0.38	0.04	1.42	15.20	37.30
Lake Whitefish	2	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-
	21	-	-	-	-	-	-	-
	22	-	-	-	-	-	-	-
	25	-	-	-	-	-	-	-
	26	-	-	-	-	-	-	-
Inconnu	7	<0.10	15.30	<0.10	0.09	1.05	24.20	75.40
	2	-	-	-	-	-	-	-
Pike	1	-	-	-	-	-	-	-

Table 10.1. (continued)

Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Sample No.	Trace Metals in Muscle (ug/G, wet wt.) Pb	Cu	Cd	Hg	Se	Zn	% moist	Liver Parasites Species[1]	#	Liver Color[2]
Burbot	4	<0.05	0.16	<0.01	0.48	0.29	5.32	82.70	R.A.	14	DB
	5	<0.05	0.13	<0.01	0.50	0.48	2.94	81.60	-	-	-
	6	<0.05	0.22	<0.01	0.14	0.40	4.94	78.00	-	-	W
	9	<0.05	0.16	<0.01	0.22	0.59	3.39	79.40	-	-	W
	10	<0.05	0.20	<0.01	0.16	0.39	5.94	81.00	-	-	W-PB
	11	<0.05	0.18	<0.01	0.22	0.33	5.19	82.30	R.A.	1	W-PB
	12	<0.05	0.31	<0.01	0.19	0.34	5.94	81.70	-	-	PB
	13	<0.05	0.14	<0.01	0.30	0.60	3.70	81.20	-	-	W
	14	<0.05	0.28	<0.01	0.21	0.34	5.81	83.60	R.A.	1	DB
	15	<0.05	0.15	<0.01	0.27	0.28	4.69	82.30	R.A.	1	PB
	16	<0.05	0.18	<0.01	0.23	0.31	4.42	81.20	-	-	PB
	17	<0.05	0.26	<0.01	0.28	0.36	6.90	83.70	-	-	W
	18	<0.05	0.20	<0.01	0.23	0.34	4.92	82.20	-	-	W-PB
	19	<0.05	0.42	<0.01	0.21	0.30	7.07	84.40	R.A.	1	PB
	23	<0.05	0.21	<0.01	0.26	0.48	4.67	79.80	R.A.	1	W-BL
	24	<0.05	0.33	<0.01	0.34	0.63	4.96	80.70	-	-	W
Lake Whitefish	2	<0.05	0.17	<0.01	0.10	0.35	3.13	77.40	-	-	-
	3	<0.05	0.31	<0.01	0.09	0.32	4.12	79.70	-	-	-
	8	<0.05	0.12	<0.01	0.08	0.35	3.38	78.70	-	-	-
	21	<0.05	0.12	<0.01	0.23	0.52	3.01	79.00	-	-	-
	22	<0.05	0.19	<0.01	0.11	0.30	3.15	82.30	-	-	-
	25	<0.05	0.07	<0.01	0.06	0.62	3.12	79.00	-	-	-
	26	<0.05	0.26	<0.01	0.10	0.28	3.19	78.10	-	-	-
Inconnu	7	<0.05	0.16	<0.01	0.10	0.39	2.84	75.10	-	-	-
	2	<0.05	0.11	<0.01	0.10	0.42	2.66	79.80	-	-	-
Pike	1	<0.05	0.34	<0.01	0.26	0.25	4.17	79.40	-	-	-

[1] Parasites species: R.A. - Raphidascaris acus.

[2] Liver color: W - white; W-PB - white to pale brown; PB - pale brown; DB - dark brown; W-BL - white with dark brown mass on tip.

11. AQUATIC MONITORING STUDY

Agency Responsible

Department of Fisheries and Oceans
Resource Impact Division, Arctic Resource Assessment Section.

Start-up Date

Winter 1983

Objectives

The objectives of the Department of Fisheries and Oceans' aquatic monitoring study are:

1. to determine the effects of the winter construction and year-round operation of the Norman Wells pipeline on fish, fish habitat, and benthos, and
2. to assess the implications of such impacts to similar northern developments.

The emphasis of the project is to document environmental change, both spatially and temporally, as a result of the project. Two major concerns are being addressed:

1. The construction of pipeline stream crossings may disrupt fish migrations and destroy critical spawning, nursery, and overwintering habitats. During and after construction, subgravel water flows may be interrupted or redirected, adversely affecting overwintering habitats.

2. The use of wood chips as insulation on stream slopes may have deleterious effects on water quality and fish habitat,

and their use may

a) cause degradation of fish habitat through the introduction of wood chips onto the stream substrate, or

b) result in decreased dissolved oxygen in the stream by increasing biological demand.

Locations

Two streams have been chosen for the intensive portion of the study based on:

1. fish overwintering potential,
2. size of stream and ease of data collection,
3. access, and
4. quality and quantity of background data.

The streams under study are Hodgson Creek (KP 305) (Figure 11.1) and Whitesand Creek (KP 271). The former is receiving by far the most intensive effort and provides the focus for study of the effects of construction on fish and benthos. Whitesand Creek provides a site for study of the effects of wood chip slope insulation on fish habitat and water quality.

Results to Date

Efforts during the 1983 study year were directed primarily at final site selection and refinement of sampling methods. No data were collected.

In 1984, pre-construction data were collected from sampling sites on a periodic basis. As well, a small camp was erected upstream of the pipeline on Hodgson Creek and actual construction monitoring began in December. The latter was in conjunction with the right-of-way clearing and timber bridge building by IPL contractors.

During 1985, a field crew was on site at Hodgson Creek continuously from mid-January until the end of February and periodically thereafter. Trenching, pipe laying, and backfilling took place at both Whitesand Creek and Hodgson Creek.

During 1986, sampling was continued during winter, summer, and fall periods (Table 11.1)

Stream velocity and discharge

Velocity measurements and discharge determinations were made in Hodgson Creek over the course of the study (with measuring techniques biased toward low flow conditions) in an attempt to determine any changes in stream flow rate as a result of pipeline construction or operation. Concerns were that diverted stream flow might cut off oxygenated water to fish overwintering areas downstream, or that operation of an ambient temperature pipeline in discontinuous permafrost might cause ice-bulb formation under the stream bed, thus decreasing subsurface flow and eventually lowering downstream flow rates. Data collected to date indicate that these concerns were not valid.

Stream Morphology

Basal flow in Hodgson Creek is provided by a spring source. Upstream of this point, the floodplain is confined within steep banks; downstream, banks are low and the stream channel follows an irregular path within a cobble floodplain. The floodplain itself is active laterally.

Virtually no change in channel configuration occurred within the study area from July 1984 to July 1985. However, as a result of a severe flood event in 1986, Hodgson Creek has shifted to the north

side of its floodplain in the vicinity of the pipeline right-of-way. This main stream channel has eroded the north bank of the floodplain and is now flowing very near to, or outside of, the area of pipe protected by deep burial and saddle weights. Many changes in channel configuration along the entire length of our study area are evident. As well, a stream cut-off channel has begun to form to the south of the main channel with resultant flow across and down unprotected stretches of the pipeline alignment. If this channel becomes established further, all flow may cross the installed pipeline at a point approximately 100 m south of its present course. Station U1 (Figure 11.2) on Hodgson Creek is at the approximate upstream limit of ice-cover in mid-winter. Depending on daily weather conditions in winter, this point may shift downstream approximately to the pipeline right-of-way. From this point downstream, flow is generally under ice. Further downstream are extensive aufeis fields, and eventually, under-ice flow is probably cut off completely.

Near Wrigley, another spring source keeps an area of Hodgson Creek ice-free. The chemical makeup of this flow is much different than that in the study area.

Sediment Deposition

Construction activities in Hodgson Creek led to a dramatic but short-term rise in levels of sediment deposition at proximal downstream sites. Deposition rates essentially reverted to pre-construction levels by February 19, two days after construction activities ceased. Most deposited material was inorganic in nature.

Water Quality

1. Suspended Solids:

Prior to construction, winter concentrations of total suspended solids (TSS) at all stations were generally less than 2 $mg.L^{-1}$. Concentrations at stations unaffected by construction remained at about this level.

Construction activities affected TSS levels, increasing concentrations to a recorded high of 26 $mg.L^{-1}$ at Station B on December 6, 1985. By approximately seven hours after the peak, the TSS concentration at this station had decreased to approximately the pre-construction value.

Analysis of suspended sediment samples from Hodgson Creek in February 1985 indicated that pre-construction levels were approximately 1 $mg.L^{-1}$ and that trenching activities increased this to a recorded high of 3524 $mg.L^{-1}$ at the most proximal downstream site on February 16. Backfilling on February 17 caused a somewhat lesser increase in suspended sediment values. High suspended sediment levels at downstream sites attenuated quickly, both over time and distance, and had reverted essentially to pre-construction values by February 21.

Values of TSS do not show a direct spatial attenuation due to the pulsed nature of sediment loading. It was not possible to follow a particular pulse of sediment-laden water as it progressed downstream; therefore, values from one station to the next are not directly comparable.

Sediment added to the water column as a result of construction activities was comprised mainly of inorganic material as

evidenced by the large decrease in percent organic material in these samples.

Total suspended solids concentrations dropped to <10 mg/L at all downstream locations within one day of trench backfilling being completed.

The highest natural concentration found in Hodgson Creek was 369 $mg.L^{-1}$ on June 1, 1985 at Station U2; however, this value should not be considered indicative of high values which occur during spring freshet.

2. Temperature:

Pipeline construction had no discernible effect on water temperature in Hodgson Creek.

3. Dissolved oxygen:

Pipeline construction had no apparent effect on dissolved oxygen levels.

4. Nutrient elements, cations, anions, and miscellaneous measurements:

Pipeline construction activities appeared to have no effect on concentrations of any of the parameters measured.

5. Benthic Drift:

The effect that increased sediment levels and sedimentation has on benthic drift was determined by the establishment of benthic drift stations (consisting of three drift nets at each station)

both upstream and downstream of the pipeline.

Construction of the pipeline caused a significant increase in drift of stoneflies and mayflies. Populations did not appear to recover until after the spring freshet. No detrimental effect of this loss of food supply on fish was detected, possibly because construction occurred across suboptimal overwintering habitat (ie. the main overwintering area for fish is upstream of this location) or because loss of food organisms was confined to a relatively small area.

Fish Species

Hodgson Creek, in the vicinity of the study area, provides year-round habitat for Arctic grayling, slimy sculpin, lake chub, longnose sucker, burbot, and northern pike. While Hodgson Creek in its entirety appears to provide good summer habitat for these species, the overwintering area seems to be restricted to a fairly limited area which is transected by the IPL pipeline (overwintering may also be possible in a short open water stretch near Wrigley but we have not observed or captured any fish at this location). Highest concentrations of fish in winter are found in pools in open water areas of Hodgson Creek. Ice-covered areas downstream of the pipeline were found to harbour fish during winter, but sampling to date in these areas indicates that numbers are not high and fish do not tend to congregate there. We believe that all flow in Hodgson Creek is

cut off by aufeis fields which begin to form at Station D3 (Figure 11.2) and build up downstream. Flow was found at Station D5 in 1985 but attempts to pinpoint flow downstream from this location have not been successful. Aufeis fields downstream of Station D5 are very extensive.

To ascertain whether any downstream emigration would occur as a result of construction activities, a hoop net was maintained at approximately Station D5 (Figure 11.2) in 1985, and was believed to effectively capture all downstream emigrants. The number of fish captured is not believed to represent a high proportion of those occupying the area, and we concluded that the small downstream migration observed does not represent an avoidance behaviour.

1. Arctic grayling:

Arctic grayling were the main fish species of interest in this study. Mature Arctic grayling were not well represented in winter sampling and it is likely that this group utilizes the stream on a seasonal basis only, using it for spring spawning, summer and fall feeding, and then moving downstream to the Mackenzie River prior to freeze-up. The overwintering group is comprised almost entirely of juvenile and young of the year.

Stomach content analyses indicated that there were no apparent effects on feeding habits of fish as a result of pipeline construction activities.

Effects of Woodchip Insulation

Water samples were taken on a periodic basis and shipped refrigerated to Winnipeg for detailed analyses.

There has been as yet no slumping of wood chip material into the stream which could cause an increase in oxygen demand or a deterioration of fish habitat. Water samples are being analyzed for organic acids and no trends are evident as yet.

Future studies

The study will continue through 1986/87 and possibly longer if results dictate. Hodgson Creek is showing signs of a possible stream cutoff in the area of the pipeline crossing. If this occurs, exposure of the pipe may result, leading to possible further impact.

Reports available

McKinnon, G.A. and F.N. Hnytka 1986. The Effect of Winter Pipeline Construction on the Fish and Fish Habitat of Hodgson Creek, NWT. A report to the Norman Wells Reserch and Monitoring Working Group. Unpubl. Rept. Department of Fisheries and Oceans. 46pp.

McKinnon, G.A. 1984. Norman Wells to Zama Oil Pipeline. Aquatic Monitoring Study. Proposal and Progress Report. November 1984. Unpubl. Rept. Resource Impact Division. Department of Fisheries and Oceans. 5pp.

Young, R.J. 1986. The Effect of Winter Oil Pipeline Construction on the Benthic Macroinvertebrate Community Structure of Hodgson Creek, NWT. M.Sc Thesis. Univ. of Guelph. 67pp.

Contact

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Figure 11.1 Map of the Northwest Territories showing the Norman Wells pipeline alignment.

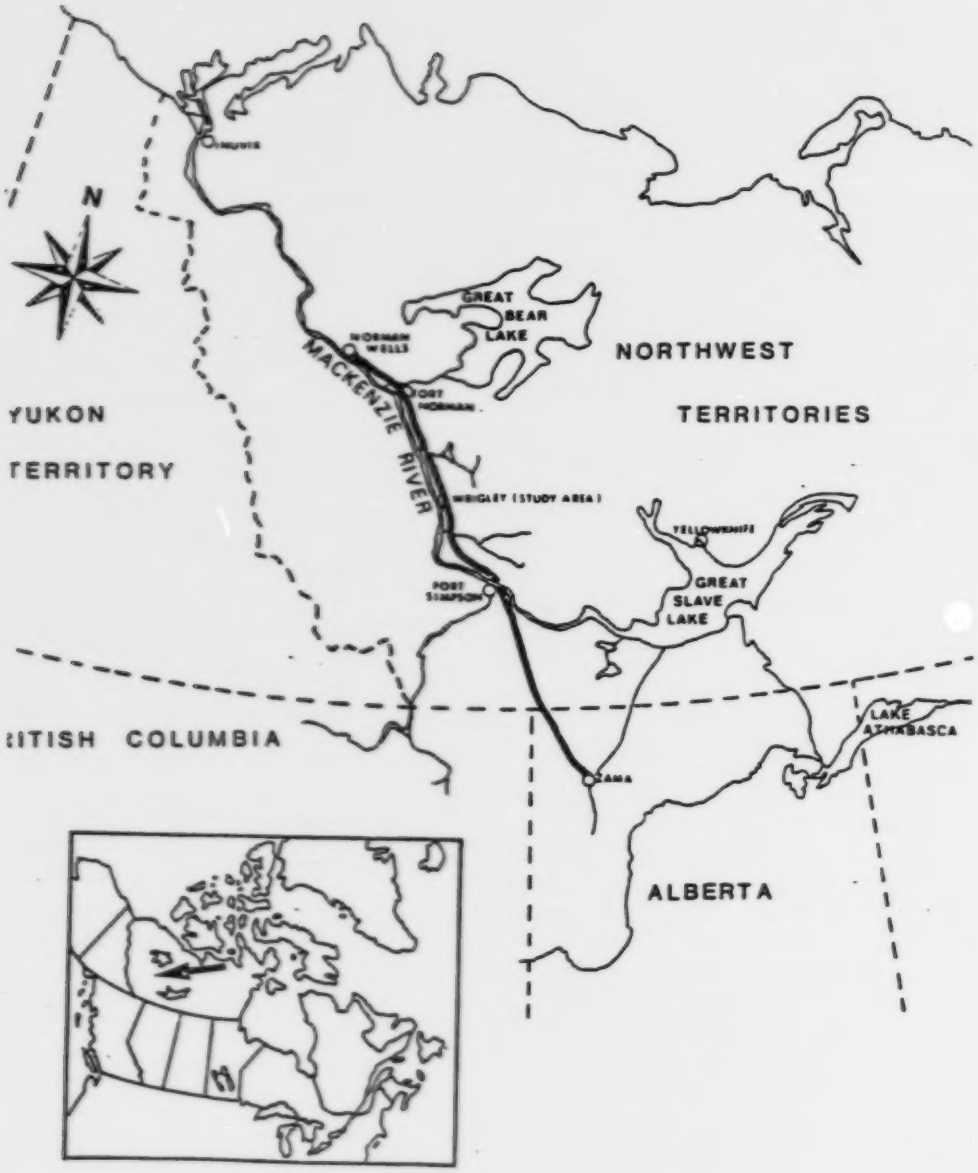

Figure 11.2 Map of the study area showing sampling locations.

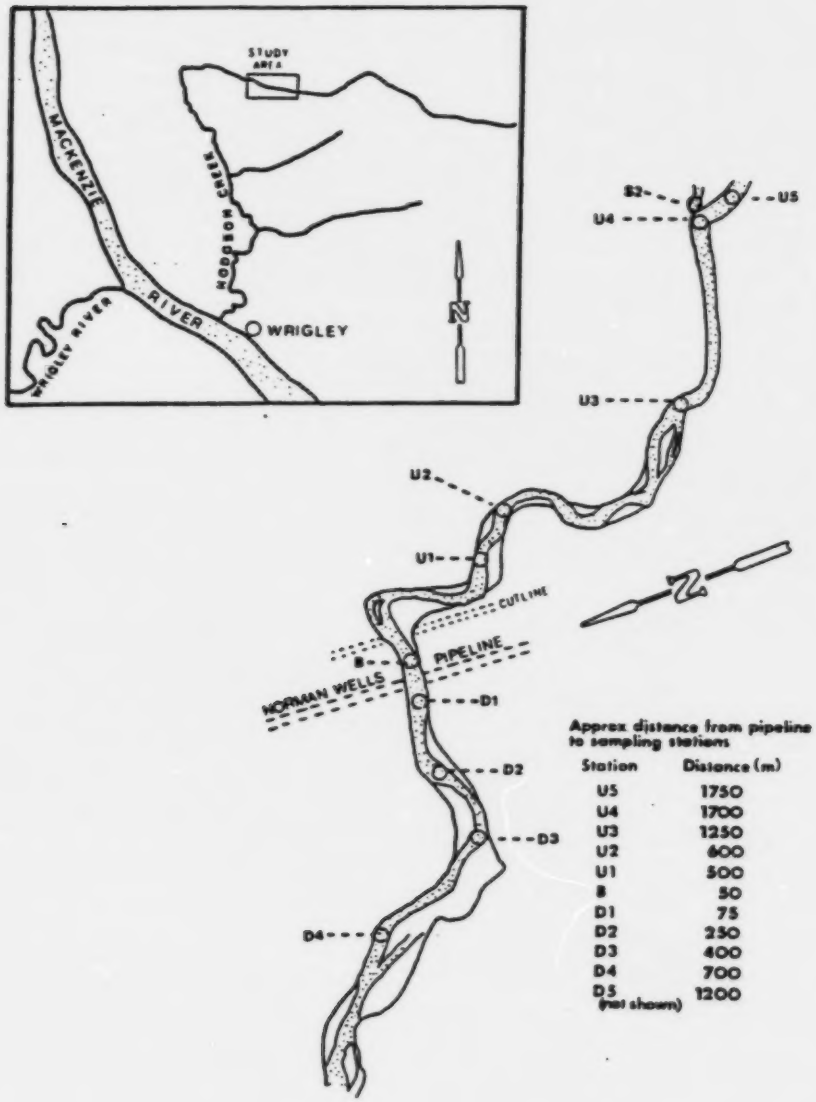

Table 11.1 Summary of sampling periods for Hodgson Creek, 1983-1986

Year			
1983	1984	1985	1986
Sampling Period:			
March 25 - 31	January 30 - February 7	January 19 - February 20	January 30 - February 1
June 4	June 24 - July 7	March 19 - 21	May 30 - June 2
July 17 - 26	August 24 - 28	May 31 - July 21	August 17 - 19
October 11 - 20	October 23 - 25 December 6 - 7	October 19 - 20	

12. SNOW GOOSE HABITAT USE

Agencies Responsible

Canadian Wildlife Service, Environment Canada in cooperation with Esso Resources Canada Limited.

Start-up Date

May 1983

Objectives

1. to determine spring waterfowl staging use of Mackenzie River islands and shorelines upstream and downstream of Norman Wells,

2. to determine the relative importance to waterfowl of habitat in the Norman Wells area compared to habitat upstream and downstream,

3. to determine the relative importance of factors influencing the use of habitat along the Mackenzie River by spring staging snow geese,

4. to assess the influence of the oilfield expansion project on spring snow goose use of Mackenzie River habitat, and

5. to identify key habitat areas important to snow geese in the spring and priority areas for protection in the event of an oil spill originating from the Norman Wells area.

Locations

See Figures 12.1 and 12.2.

Results to Date

1. In 1985, the Norman Wells area received the most use by snow geese on only one of the days surveyed; on the other three days, geese were more numerous in other reaches.

2. Use of the Norman Wells area by snow geese in 1985 was roughly equivalent to the level that occurred in 1984. However, peak use (2516 birds) of this reach was low compared to other years studied. Substantial use was made of the Windy Island area due to low water levels which caused mudflats to be exposed in 1985 (Table 12.1).

3. Based on data collected in 1972, 1980, 1981, 1983, 1984, and 1985, the following reaches are considered to be the most important for snow geese (Figure 12.3):

   a. Windy Island area;
   b. Ten Mile Island - Mac Island;
   c. Ogilvie Island - Patricia Island;
   d. Beavertail Point - Hume Island; and
   e. a section of the Fort Good Hope - Tieda River reach.

   Of these reaches, the Norman Wells area (Ten Mile Island - Mac Island reach) is probably the most heavily used on a consistent basis. The Beavertail Point - Hume Island reach ranks second in importance.

4. Mackenzie River islands and shorelines are very important for

snow geese during spring migration because virtually no other suitable habitat, free of snow and ice, exists on either side of the river. Brackett Lake is the only off-river area between Mills Lake, at the western end of Great Slave Lake, and the Mackenzie Delta, which offers attractive staging habitat conditions in the spring.

Disturbance Response of Waterfowl

1. Helicopter service flights were the chief sources of waterfowl disturbance associated with Esso's oilfield expansion project at Norman Wells in 1983 and 1984. Snow geese were the most sensitive of all waterfowl to aircraft flights. For the most part, the response of waterfowl to aircraft disturbance was minor and short term. When birds took flight, they most often returned to the same staging area within three minutes or less. This general trend was also observed in 1980 and 1981 by R. Webb, Environmental Services Ltd. In 1983, aircraft flights at altitudes of between 150 and 500 m above ground level (agl) produced the highest frequency of response by waterfowl. Only 8 % of Esso's low altitude (less than 150 m) helicopter flights caused any disturbance of waterfowl.

   Almost all of the aircraft flights in 1983 followed routes which were located more than 0.5 km from staging bird flocks. Considering all aircraft types, 70 % of the flights which occurred between 0.5 and 1.0 km from staging waterfowl produced a noticeable response. At distances between 1.0 and 5.0 km, only 11 % of the flights caused a response. With only one exception, waterfowl did not respond to flights which occurred more than 5.0 km away.

2. Snow goose response to helicopter flights at Norman Wells in 1985

was minor and short term in nature, according to the casual observations made that year. On the basis of the data collected in all three years of study, it is concluded that snow geese experienced only minor disturbance as a result of the oilfield expansion and associated activities at Norman Wells.

Factors Influencing Response to Disturbance

A review of literature available on the response of snow geese to aircraft disturbance indicates that the response is influenced by several factors, including:

1. aircraft type,
2. altitude in combination with distance,
3. weather (eg. visibility, wind),
4. stage in life cycle of bird,
5. age of bird.

If specific guidelines for aircraft activities could be established on the basis of the Norman Wells studies, they would probably only apply to other developments with the same study area. Reactions to aircraft were only studied at Norman Wells. It is quite conceivable that, had the disturbance response of snow geese been studied, for example, at the well-used area upstream of Hume Island, a different pattern may have been observed. One reason for this would be that aircraft and other human activities, not related to the Norman Wells Project, had occurred at Norman Wells for many years prior to the project. In other words, if a proposal was put forward to construct six more artificial islands in the Windy Island area near Fort Norman, the response of snow geese to aircraft activity would not necessarily follow the same pattern as observed at Norman Wells.

It is apparent, therefore, that it would be meaningless to construct very specific and binding guidelines specifying distance and

elevation restrictions for aircraft used in conjunction with all northern developments. There are, however, more general measures and guidelines which, when observed, should serve to minimize disruption of waterfowl populations. These are listed in the following section.

Recommendations

1. There is a real advantage to both the developer and regulatory agencies for open dialogue to occur between staff members directly involved in the planning and execution of the development, early in the planning stages. This allows for pre-project baseline conditions to be studied and monitoring studies to be designed cooperatively.

2. To avoid possible problems in interpretation of results due to different methodologies used, consistent approaches should be followed by consultants conducting the pre-project, during project, and post-project monitoring studies.

3. Habitat distribution information and wildlife use data are valuable components of a baseline data collection program. Having this information enables decisions to be made concerning siting of facilities, routing of aircraft, and other aspects of a development.

4. Because the responses of waterfowl to the development activities may be different from that observed at Norman Wells, close communication between the developer, the consultant, and regulatory agencies is important. This allows for more or less stringent precautions to be taken should a greater or lesser sensitivity to disturbance than expected be noted.

5. On the basis of the Norman Wells experience, we would recommend

helicopters operate at altitudes not exceeding 150 m above ground level and maintain a minimum distance of 0.5 km from snow goose flocks.

6. It is essential to have a monitoring program in place at the start-up time of the development where the possibility for waterfowl disturbance exists. Included in the program should be studies to determine the actual responses of snow geese and other waterfowl to disturbance. In the case of aircraft flights, the methodology used should allow the combined influence of altitude and distance on disturbance response to be measured.

7. It is important that flight controls, such as altitude, distance, exclusion areas, corridors, etc., are spelled out as much as possible in the permit or authority given by the regulatory agency concerned. It is equally important that these controls are made known to the pilots of companies providing flying services to the developer.

Reports Available

Boothroyd, P.N. 1984. Monitoring of Snow Goose Populations on the Mackenzie River During Spring Migration - 1983, 1984. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 4pp.

Boothroyd, P.N. 1985. Spring use of the Mackenzie River by snow geese in relation to the Norman Wells Expansion Project. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 211pp.

Boothroyd, P.N. 1986. Influence of the Norman Wells oilfield expansion project on snow geese. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 60pp.

Sikstrom C.B. and P.N. Boothroyd. 1985. Resolving production drilling restrictions and waterfowl disturbance concerns during spring migration at Norman Wells, Northwest Territories, Canada. Proc. Conf. on Northern Hydrocarbon Development. Environmental Problem Solving, held at Banff, Alberta Sept. 24-26, 1985.

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Figure 12.1 The Norman Wells oilfield study area.

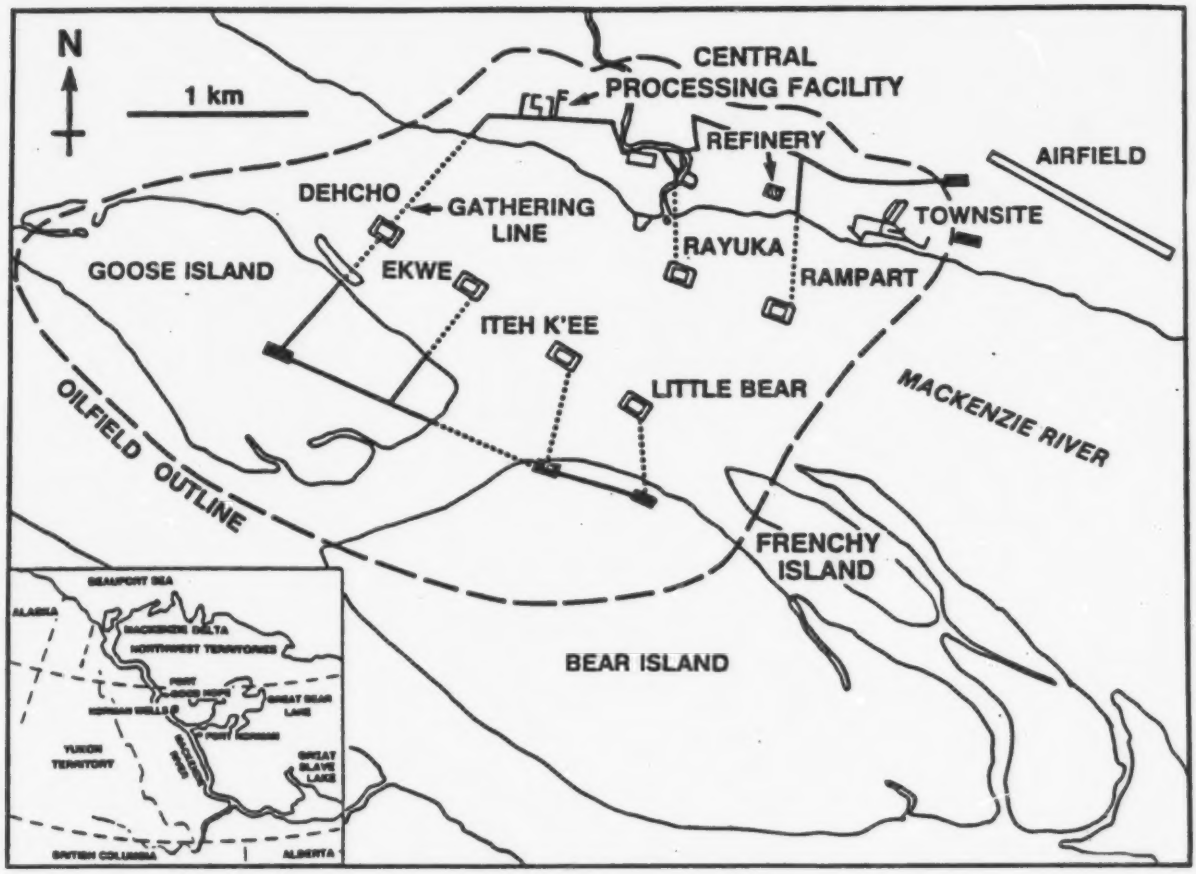

Figure 12.2 Geographic features and locations of reaches in the study area

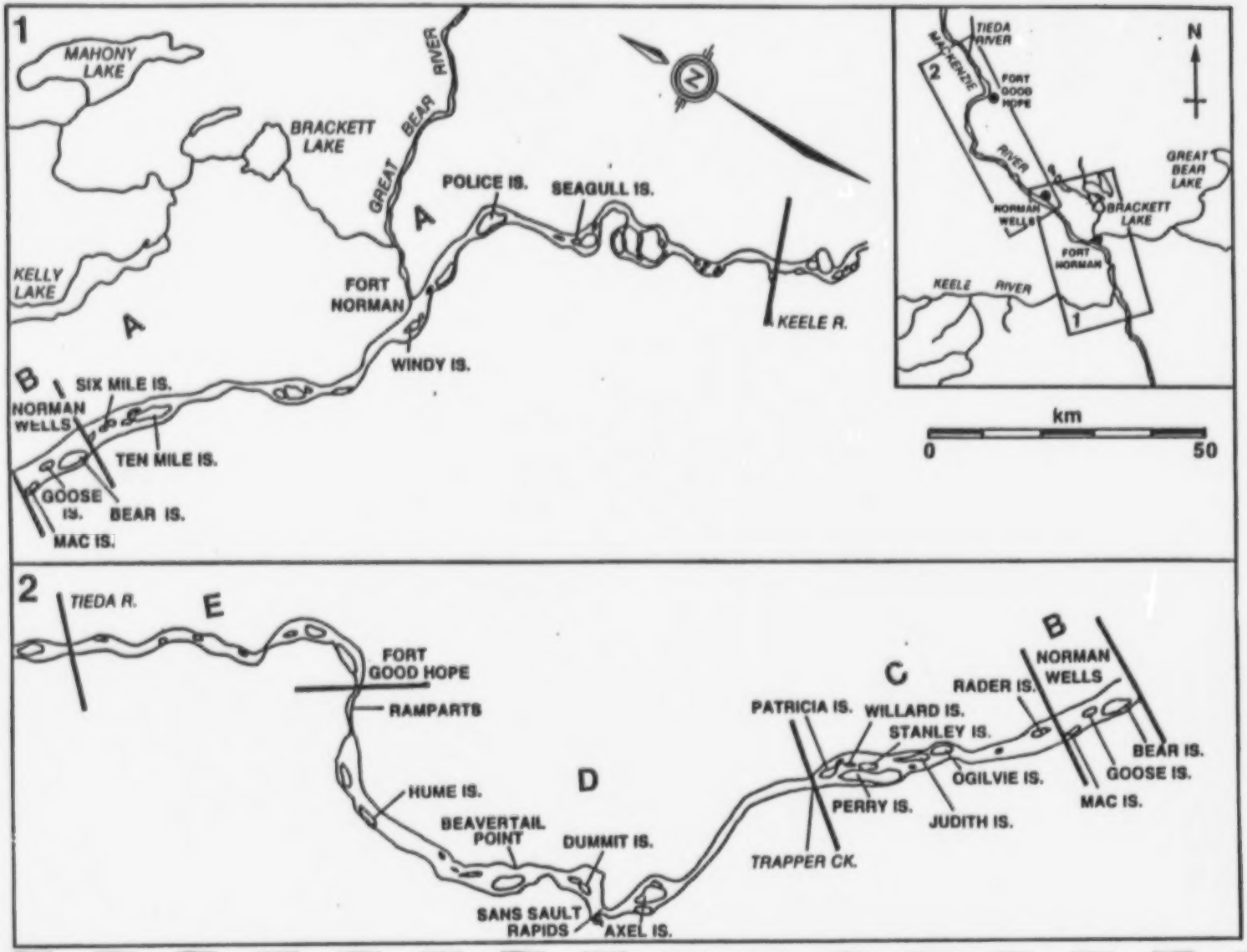

Figure 12.3 Locations of important snow goose staging areas in the study area

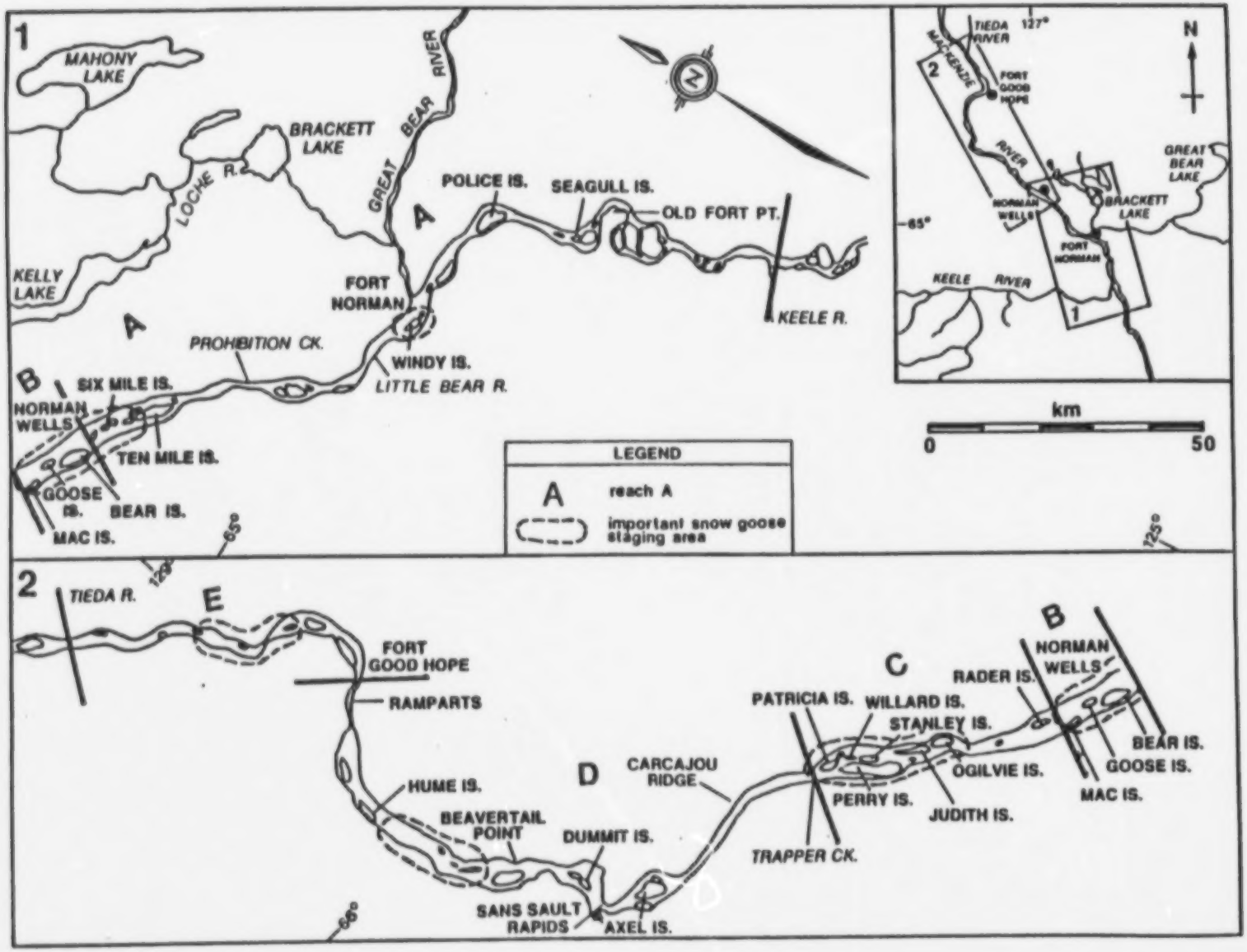

Table 12.1 Numbers and distribution of snow geese observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1972, 1980, 1981, 1983, 1984 and 1985.

REACH	YEAR	2	4	6	7	8	9	10	12	13	14	16	16	17	18	19	20	23	24	25	29
A	1972[a]	.[b]	.	.	.	.	.	.	.	22 410	.	.	9 725	.	.	.	661	.	.	-[a]	-
(KEELE R. -	1980[c]	6 500[a]	6 500[a]	.	.	.	25 975	.	.	.	.	4 700	.	.	.	.	.	.	.	.	.
SIX MILE IS.)	1981[d]	20[a]	.	.	25[a]	.	-[a]	-[a]	.	-[a]	.	.	.	.	.	.	.	.	.	.	.
	1983[e]	-	.	-	.	333	.	428	-	25[a]	.	.	.	1 940[a]	12 136[a]	.	.	7 663[a]	-[a]	.	-[a]
	1984[b]	.	.	.	.	427	.	-	11	.	.	6	.	.	.	.	.	.	.	.	.
	1985[b]	.	.	.	.	.	.	1 162	.	6 902	.	1 943	.	-	.	.	.	.	.	.	.
B	1972	.	.	.	.	.	.	.	.	12 232	.	.	25 650	.	.	.	3 645	.	.	286	182
(BEAR IS. -	1980	3 700	900	7 000	.	.	.	.	.	.	4 800	5 560	.	.	.	-	.	.	.	.	.
MAC IS.)	1981	16	.	500	900	.	35	32	.	-	.	.	.	.	.	.	.	.	.	.	.
	1983	-	.	-	.	40	.	762	1 670	1 404	.	.	.	4 270	14 920	.	.	9 062	3 364	.	2
	1984	.	.	.	.	3 226	.	1 096	756	.	.	810	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	1 434	.	1 106	.	2 816	.	1	.	.	.	.	.	.	.
C	1972	.	.	.	.	.	.	.	.	1 673	.	.	5 438	.	.	.	661	.	.	25	-
(RADER IS. -	1980	.	.	.	.	.	.	.	.	.	.	4 026	.	.	.	.	.	.	.	.	.
PATRICIA IS.)	1981	400	.	750	-	.	.	-	.	5	.	.	.	.	.	.	.	.	.	.	.
	1983	-	.	-	.	90	.	45	353	907	.	.	.	1 100	715	.	.	5 361	6 507	.	-
	1984	.	.	.	.	3 266	.	3 017	1 611	.	.	736	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	250[f]	.	1 800	.	350	.	-	.	.	.	.	.	.	.
D	1972	.	.	.	.	.	.	.	.	6 329[f]	.	.	9 949[f]	.	.	.	6 230[h]	.	.	1 326	30[f]
(TRAPPER CREEK	1980	.	.	.	.	.	.	.	.	.	.	256	.	.	.	.	.	.	.	.	.
- RAMPARTS)	1981	180	.	-[h]	-[h]	.	.	-[h]	.	-[h]	.	.	.	.	.	.	.	.	.	.	.
	1983	-	.	-	.	80	.	-	10	2	.	.	.	-	20	.	.	3 426	3 462	.	6
	1984	.	.	.	.	3 284	.	5 670	2 002	.	.	656	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	.	.	2 370	.	6 163	.	2 127	.	.	.	.	.	.	.
E	1972	.	.	.	.	.	.	.	.	.	.	.	1 050	.	.	.	4 535	.	.	6 529	-
(FORT GOOD HOPE	1980	.	.	.	.	.	.	.	.	.	.	6 400	.	.	.	.	.	.	.	.	.
-TIEDA R.)	1981	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1983	-	.	-	.	-	.	-	-	-	.	.	.	853	3 316	.	.	16 930	16 214	.	-
	1984	.	.	.	.	1 100	.	770	1 700	.	.	1 656	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	.	.	6 550	.	2 760	.	266	.	.	.	.	.	.	.

[a] CAMPBELL AND SHEPARD (1973)

[b] . = NOT SURVEYED

[c] - = NO SNOW GEESE OBSERVED

[d] R. WEBB ENVIRONMENTAL SERVICES LTD. (1980)

[e] TEN MILE ISLAND - SIX MILE ISLAND

[f] R. WEBB ENVIRONMENTAL SERVICES LTD. (1983)

[g] MAY 3, 8 AND 10 - CANADIAN WILDLIFE SERVICE; MAY 6, 12, 13, 17, 18, 23, 24 AND 29 - McCOURT MANAGEMENT

[h] CANADIAN WILDLIFE SERVICE

[i] RADER ISLAND - JUDITH ISLAND

[j] DUMMIT ISLAND - HUME ISLAND

[k] DUMMIT ISLAND - RAMPARTS

[l] TRAPPER CREEK - SANS SAULT RAPIDS

13. RAPTOR MONITORING PROGRAM

Agencies Responsible

Government of the Northwest Territories, Department of Renewable Resources in cooperation with Interprovincial Pipe Line (NW) Ltd.

Start-up Date

Spring 1983

Objectives

1. to determine the effects of pipeline construction and operation on nest site occupancy and reproductive success,
2. to document the behavior of raptors nesting in the potentially sensitive zone within 3.2 km of the pipeline route, and
3. to determine if the environmental protection measures for birds of prey are effective.

Locations

Figure 13.1 shows the general location of the pipeline and control study areas.

Results to Date

First Year Observations and Results - 1983

1. Arrival and Departure

Raptor surveys were conducted by the Department of Renewable Resources in April and September to determine if the "restricted" construction period as defined by IPL was appropriate to protect nesting birds of prey.

Ground surveys were conducted near Norman Wells, Fort Norman, and Fort Simpson during April to determine birds' arrival dates at nest sites.

First sightings:

Peregrine Falcon	April 12, 1983	Norman Wells

A departure survey on September 14 showed recent activity at Peregrine Falcon and Golden Eagle nests. Neither raptors were observed in the nesting areas at the time, but Golden Eagles could still be found in the Norman Wells area.

The "restricted" construction period was considered to be adequate to protect nesting raptors.

2. Compliance Monitoring

Only one IPL facility site was developed during the nesting season within the 3.2 km sensitive zone. Development schedules required construction activities within the protected zone. These were conducted on a "restricted" activity basis.

3. Nest Site Occupancy and Reproductive Success

Aerial surveys were conducted in June to observe nest site occupancy; surveys in July showed reproductive success along the pipeline route and in a control area not affected by pipeline activities. Eighteen nests were observed between Fort Simpson and Norman Wells. Each of nine "control" areas northwest of Norman Wells had at least one historical Peregrine eyrie. All active Peregrine nests produced young.

4. Disturbance Monitoring

As there were no occupied raptor nests within 3.2 km of any development site, raptor disturbance monitoring was not conducted in 1983.

Second Year Observations and Results - 1984

A total of 14 areas were surveyed along the pipeline route in 1984. Of these, 13 had been previously identified by IPL (1982). These areas included two mainline construction camps and the Mackenzie River crossing at KmP 526. New construction sites for 1984 were also surveyed (Wrigley Pump Station and construction camps at KmP 226 and 285).

A survey to observe nest site occupancy in June was followed by a survey to observe production in July. These surveys were conducted along the pipeline route and in the "control" area.

1. Arrival and Departure

Information on bird arrivals in the nesting area was collected on a weekly basis from mid-March. Ground surveys were conducted near Norman Wells, Fort Norman, and Fort Simpson. Known nesting sites (1984) between Norman Wells and Wrigley were surveyed in September for the presence of raptors. A similar survey was conducted in the control areas. At that time, no raptor sightings were made.

First Sightings:

Peregrine Falcon (1 female)	April 12, 1984	Bear Rock
Peregrine Falcon (1 pair)	April 24, 1984	Norman Wells
Golden Eagle	March 26, 1984	Fort Simpson
Golden Eagle	March 29, 1984	Norman Wells
Bald Eagle	April 3, 1984	Fort Simpson

The "restricted" period (April 15 - September 15) was considered adequate in 1984.

2. Compliance Monitoring

Construction activity occurred at Camp 78, KmP 67, and at the south

shore of the Mackenzie River crossing. While all of these areas are within the 3.2 km sensitive zone for nesting raptors, construction activities were not prohibited. IPL informed its contractors of special procedures to minimize disturbances.

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Surveys in June focussed on nest site occupancy while July surveys recorded productivity. Thirty nine nests were recorded on each flight (34 stick nests, 5 ledge nests) of which 30 stick nests and 4 ledge nest were inactive. All nests which were active were also productive.

b. Control Raptor Areas

Twenty nine stick nests and 10 ledge nests were visited. Of these, 4 stick nests and 6 ledge nests were active and productive. Peregrine Falcon production and productivity for the pipeline areas decreased from 1983 with the loss of one productive nest.

Peregrine production for the control areas increased in 1984 to more than three times that of 1983.

4. Disturbance Monitoring

Survey results for 1984 indicated that no raptor nests were occupied within 3.2 km of any development sites or areas requiring summer maintenance work.

Third year Observations and Results - 1985

1. Arrival and Departure

Raptor survey methods did not change from the two previous years. Surveys for arrival and departure dates, and occupancy, were conducted within a day of the 1984 dates.

First sightings:

Peregrine Falcon	April 30	Norman Wells
Golden Eagle	April 23	Norman Wells
Bald Eagle	April 3	Fort Simpson

The departure surveys conducted along the pipeline route and control areas resulted in several raptor observations in the vicinity of nest sites active this year.

Peregrine Falcon	September 13	Control Areas
Golden Eagle	September 11	Pipeline Areas
Bald Eagle	Sept. 8 - 14	Pipeline Areas
Buteo sp. (unidentified hawk)	Sept. 8 - 14	Pipeline Areas

This was the first year of the monitoring program that raptors were observed on their territories at the time of the departure surveys.

IPL's raptor protection measures were considered satisfactory in 1985.

2. Compliance Monitoring

The construction phase of the Norman Wells Pipeline was completed by March 1985. Monitoring and maintenance activities continued during the spring and summer months with no problem areas located near raptor nest sites. Aerial overflights of the pipeline will continue on a weekly basis for the life of the pipeline. Such flights are conducted at an altitude of less than 100 m and, in some cases, pass through raptor protection zones.

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Raptor surveys conducted along the pipeline route examined the same thirteen raptor nesting areas studied in 1984. A total of 35 stick

nests and 5 ledges were surveyed during the occupancy and productivity surveys, an increase of 1 stick nest from 1984.

b. Control Raptor Areas

Raptor surveys in the control area northwest of Norman Wells noted 28 stick nests and 12 ledges in the areas surveyed in 1984. Of these, one stick nest and seven ledges were active.

4. Disturbance Monitoring

Site specific disturbance monitoring was not carried out in 1985. There were no raptor areas near concentrated maintenance or monitoring work performed by IPL.

Fourth Year Observations and Results - 1986

1. Arrival and Departure

Renewable Resource Officers in Fort Simpson and Norman Wells recorded spring arrival dates for raptors in their area. Departure dates were not recorded since field staff were not available to do the ground surveys.

First sightings:

Peregrine Falcon	not obtained	
Golden Eagle	27 March	Norman Wells
Bald Eagle	23 April	Fort Simpson

2. Compliance Monitoring

As part of Interprovincial Pipe Line's monitoring program, weekly helicopter overflights of the pipeline were continued in 1986. Summer maintenance of the right-of-way was not required near raptor nesting areas. The company and government scientists, working along the pipeline route, were informed of active nest sites to avoid during the nesting season.

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Raptor surveys conducted along the pipeline route examined the same thirteen nesting areas studied over the past two years. Thirty-two stick nests were checked during both surveys and six were occupied, four by ravens and two by Golden Eagles. During the spring survey, four known ledge nests (scrapes) were also checked. Although none of the nests were occupied, two single and one pair of territorial Peregrine Falcons were sighted at different locations. Four productive Peregrine nests were found during the productivity survey in July. Three of these nests were located at alternate nest sites and the fourth was found at a known site. A summary of raptor productivity and production for the pipeline area is given in Table 13.2.

b. Control Raptor Areas

Two raptor surveys were conducted in 1986. Thirty-five stick nests and eight known ledge nests were checked. Of these, five stick nests were occupied; two each by Golden Eagles and Ravens and one by Peregrine Falcons. None of the eight ledge nests were found to be occupied during the spring survey; however, single or pairs of territorial Peregrine Falcons were sighted in four areas. Productive nests were found in all four areas during the summer survey, but the number of young could only be determined at nests in two of these areas. One other nest was believed to be productive based on July ground observations of a territorial adult Peregrine near a known nest site.

Several species of non-nesting raptors were observed during the two surveys including two adult Golden Eagles and an American Kestrel. Productivity and production data in the control area is summarized in Table 13.3.

c. Comparison of Reoccupancy Rates

Reoccupancy rates for Peregrine nest sites in the pipeline and control areas are given in Table 13.1. The data indicate that both The pipeline and control areas have experienced similar high rates of reoccupancy. Although sample sizes are relatively small, there is little difference in reoccupancy rates for the pipeline and control areas. These figures suggest that pipeline activities have not reduced nest occupancy along the pipeline route. Reoccupancy rates were exceptionally high in 1986, since all known Peregrine nest sites were occupied. The high reoccupancy rates may be due to an increasing population of Peregrine Falcons in the Mackenzie Valley (Bromley and Matthews, 1986).

d. Comparison of Raptor Production

Tables 13.2 and 13.3 compare raptor productivity for the pipeline and control areas between 1983 and 1986. In 1986, Peregrine production in the pipeline areas was significantly greater than in other years. Eight young were produced from four nests and all occupied nests were productive. Three Golden Eagle young were also produced from two productive nests. The largest number of Golden Eagle young produced prior to 1986 was two in 1983 at a single nest site.

Peregrine production in the control areas for 1986 is estimated at twelve. Although six nests were productive, young could only be counted at three. Peregrine productivity (number of young per successful pair) of 2.0 is based on the total number of young observed from those three nests. A comparison of 1986 Peregrine productivity and production figures shows no significant difference for those years when the same study areas were examined. Golden Eagle production was lower in 1986 as a result of two unsuccessful nests.

4. Disturbance Monitoring

Disturbance monitoring at active nest sites was not carried out in 1986.

Future Studies and Recommendations

1. A final year of raptor monitoring should be carried out in 1987.

2. A final report should be produced in 1987 and include:
   a. survey data from the early 1980's,
   b. conclusions drawn from comparisons of the treatment and control areas, and
   c. an evaluation of raptor protection measures and recommendations for future development projects.

Reports Available

Bromley, R.G. and S.B. Matthews. 1986. Status of Peregrine Falcons (Falco peregrinus anatum) in the Mackenzie Valley, Northwest Territories, 1969 to 1985. In press.

Matthews, S.B. 1986. Raptor Monitoring Program, Norman Wells Pipeline Project, 1986 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 15 pp.

Matthews, S.B. 1985. Raptor Monitoring Program, Norman Wells Pipeline Project, 1985 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 15 pp.

Matthews, S.B. 1984. Raptor Monitoring Program, Norman Wells Pipeline Project, 1984 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 9pp.

Matthews, S.B. 1983. Raptor Monitoring Program, Norman Wells Pipeline Project, 1983 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 13pp.

See also references provided by Interprovincial Pipe Line (NW) Ltd. in Section 1.

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Figure 13.1

General study area for the pipeline and control raptor areas.

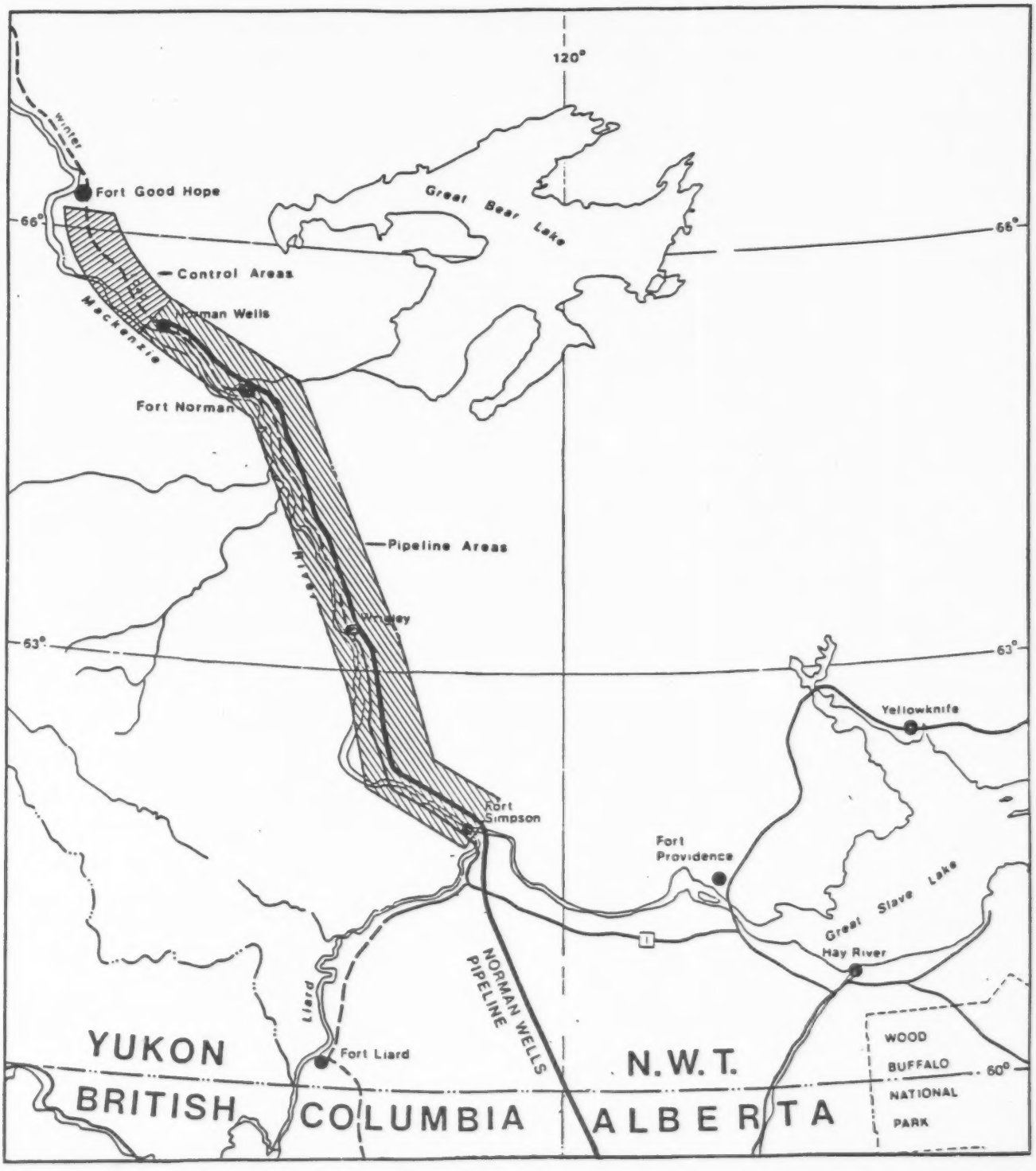

Table 13.1. Reoccupancy rates of peregrine nest sites.

Years of Comparison	No. of Nests	% Reoccupancy
Pipeline Nest Sites		
1984/1983	2/2	100
1985/1984	2/2	100
1986/1985	4/2	200
Control Nest Sites		
1984/1983	3/3	100
1985/1984	6/7	86
1986/1985	6/6	100

Table 13.2. Comparison of raptor production in pipeline study areas from 1983 to 1986.

Pipeline Raptor Areas	1983	1984	1985	1986
A	1 PF	1 PF	3 PF	3 PF
B	0	2 RT	0	0
C	4 PF	0	1 GE	2 PF[1] 1 GE
D	0	0	0	0
E	2 RT	0	0	3 PF
F	0	0	0	0
G	0	0	0	0
H	0	0	0	0
I	2 GE	1 GE	0	2 GE
J	0	0	0	0
K	0	0	0	0
L	0	0	0	0
M	0	0	0	0
Estimate of Peregrine Production	5 PF (n=2)	1 PF (n=1)	3 PF (n=1)	8 PF (n=4)
Peregrine Productivity (No. of Young/SuccessfulPair):	- x = 2.5 (n=2)	- x = 1.0 (n=1)	- x = 3.0 (n=1)	- x = 2.0 (n=4)

[1] Peregrine production in Area C is a result of 2 productive nests.

PF - Peregrine Falcon, GE - Golden Eagle, RT - Red-tailed Hawk

Table 13.3. Comparison of raptor production in control study areas from 1983 to 1986.

Control Raptor Areas	1983	1984	1985	1986
AA	0	0	1 GE	3 PF
BB	0	0	1 PF	0
CC	0	0	0	0
DD	0	2 PF	0	0
EE	2 PF	2 PF	1 PF	1 PF[1]
FF	2 GE	0	0	0
GG	1 PF[1]	4 PF	1 PF	1 PF[1]
HH	0	3 PF	3 PF	2 PF
II	2 PF	2 PF 1 GE	2 PF	1 PF[1]
JJ	-	3 PF 1 GE	3 PF	0
KK	-	3 PF	0	1 PF
Estimate of Peregrine Production	6 PF (n=3)	19 PF (n=7)	11 PF (n=6)	12 PF (n=6)
Peregrine Productivity (No. of Young/Successful Pair):	- x = 2.0 (n=2)	- x = 2.7 (n=7)	- x = 1.8 (n=6)	- x =2.0 (n=3)

[1] Peregrine production of 1 is given as a minimum where the number of young was not determined but the nest was believed to be productive.

PF - Peregrine Falcon, GE - Golden Eagle

14. WILDLIFE DISTURBANCE MONITORING

Agency Responsible

Government of the Northwest Territories, Department of Renewable Resources, in cooperation with Interprovincial Pipe Line (NW) Ltd.

Start-Up Date

Winter 1983/84.

Objectives

1. to determine the distribution and movements of big game and fur-bearers along sections of the pipeline right-of-way and adjacent areas before, during, and after pipeline construction,
2. to determine if pipeline construction activities influence wildlife movement,
3. to identify areas where wildlife conflicts may occur, and
4. to determine whether the environmental protection measures are effective and to make recommendations for future northern pipeline projects.

First Year Study Methods (1983/84)

Four study areas were selected along the pipeline route; one south of Norman Wells and three north of Fort Simpson (see Figure 14.1 for locations). Study areas were chosen by habitat types and defined by four straight-line transects, 1.5 km in length, running perpendicular to the pipeline right-of-way. Transects were surveyed every three weeks from January to April. Animal tracks were recorded when they

were observed to cross the transect lines. Information recorded included numbers of animal species, habitat type, and distance from the right-of-way.

Ground surveys were conducted along the right-of-way on Spreads 1 and 4 every three weeks to provide information on wildlife use of the pipeline corridor during construction.

Second Year Study Methods (1984/85)

The second year of the study concentrated on big game and furbearer movements, distribution, and use of the pipeline right-of-way and adjacent areas one year after construction. Field work was carried out in the same study areas with the same frequency as the first year.

Aerial surveys on Spreads 1 and 4 were conducted on a monthly basis from January to April to determine wildlife use of the right-of-way in the post-construction period.

Third Year Study Methods (1985/86)

During the third winter following pipeline construction, wildlife movements and distribution were monitored in the same study areas as in the previous two years. Wildlife surveys were conducted from both the ground and air. The frequency of the surveys was reduced to include an early, mid, and late winter examination of the wildlife transects.

Future Studies

No further work is planned.

Reports Available

A final report is in preparation.

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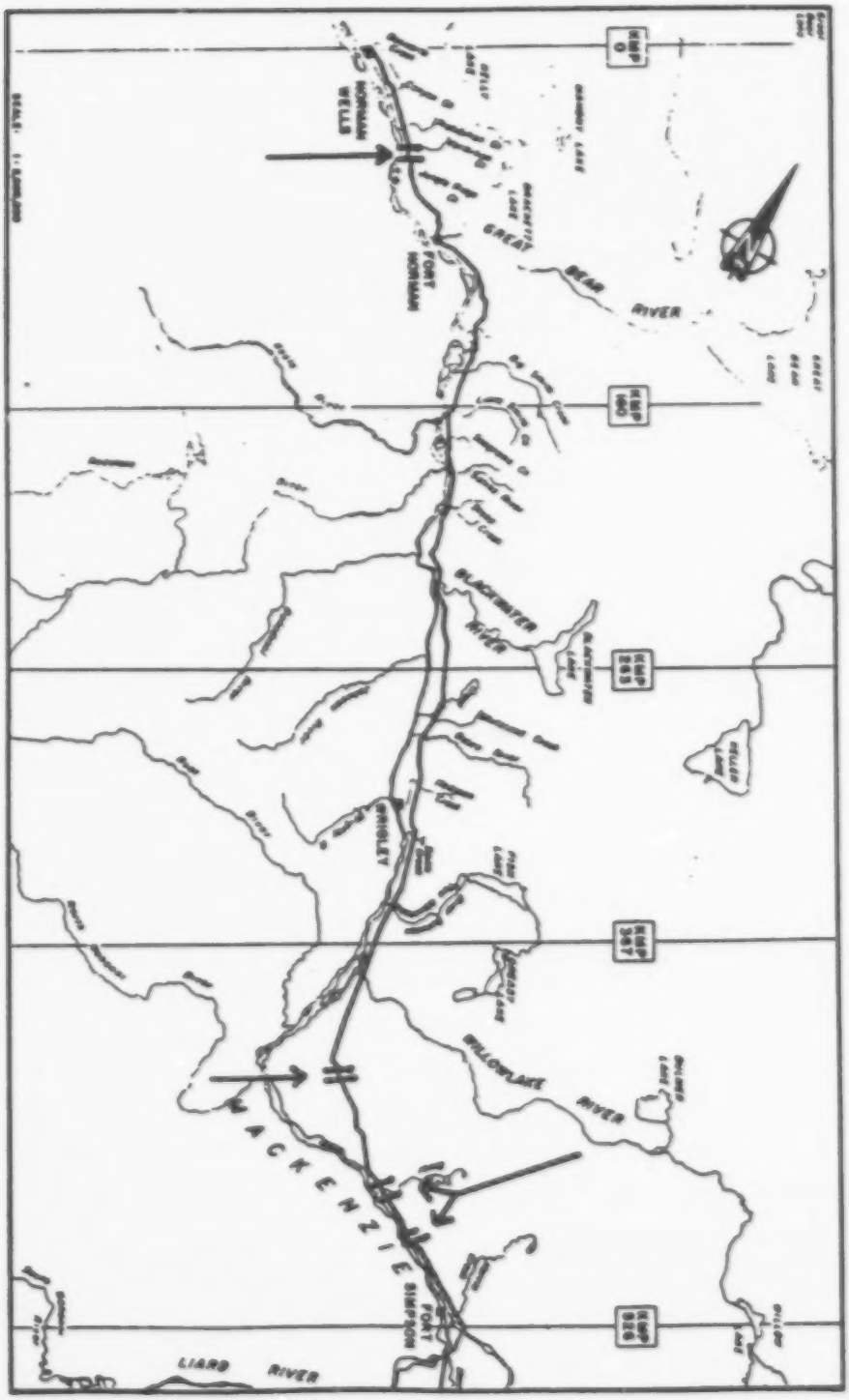
Figure 14.1 Wildlife disturbance monitoring sites



15. RENEWABLE RESOURCE HARVEST MONITORING

Agency Responsible

Government of the Northwest Territories, Department of Renewable Resources.

Start-Up Date

Winter 1984/85.

Objectives

1. to map the important hunting and trapping areas in the Fort Simpson, Jean Marie River, Wrigley, and Trout Lake areas,
2. to monitor hunting and trapping activities of General Hunting License holders in order to determine the effects of pipeline construction on renewable resource users, and
3. to determine the effectiveness of industry measures designed to minimize impacts on hunter and trapper activities.

Methods of Monitoring Harvests

Community field workers were hired to carry out a land use mapping exercise and hunter/trapper survey for each of the four communities (Wrigley, Ft. Simpson, Jean-Marie River, and Trout Lake) being studied. General Hunting License holders who were hunting and trapping were interviewed for land use information and asked to complete a questionnaire pertaining to pipeline impacts.

Results to Date

A set of community renewable resource harvesting maps at a scale of

1:250,000 has been completed.

These maps (16 in total) have been digitized and include a base map (hydrology) and five overlays. The overlays produced are:

1. Relief
2. Exploration, Development, and Transportation,
3. Family Trapping Areas,
4. Species Harvest, and
5. Traplines

Future Studies

No further work is planned.

Reports Available

Copies of the community renewable resource harvesting maps can be obtained from the Department of Renewable Resources. For more information, contact the project manager.

A report on the effects of pipeline construction on renewable resource harvesting is in preparation.

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